PB82-231432

Environmental Impacts of Special Types of Landfills

SMC Martin, Inc.
Valley Forge, PA

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

Sep 81

U.S. Department of Commerce
National Technical Information Service
NTIS

PB82-231432

EPA-600/2-81-190
September 1981

ENVIRONMENTAL IMPACTS OF SPECIAL TYPES OF LANDFILLS

by

Deborah Grant Lord
William W. Beck, Jr.
SMC-MARTIN
King of Prussia, Pennsylvania
19406

Contract No. 68-03-2620

Project Officer

Donald E. Sanning
Solid and Hazardous Wastes Research Division
Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-81-190	2. ORD Report	3. RECIPIENT'S ACCESSION NO. PB82 231432
4. TITLE AND SUBTITLE ENVIRONMENTAL IMPACTS OF SPECIAL TYPES OF LANDFILLS		5. REPORT DATE September 1981 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Deborah Lord and William Beck		8. PERFORMING ORGANIZATION REPORT NO
9. PERFORMING ORGANIZATION NAME AND ADDRESS SMC-Martin King of Prussia, Pennsylvania 19406		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. 68-03-2620
12. SPONSORING AGENCY NAME AND ADDRESS Municipal Environmental Research Laboratory - Cin., OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED Final 14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES

Project Officer - Donald E. Sanning 513/684-7871

16. ABSTRACT

Water quality was monitored for one year at a hillfill, a balefill, a millfill, a strip mine landfill, and a permitted sanitary landfill to determine the impact of each on water quality. The leachate generated by the hillfill was the strongest during initial decomposition. However, during the study period, it was in the final stages of anaerobic degradation and therefore was of low strength. The balefill produced a low strength leachate since this method of landfilling results in channeling of water through the landfill. The millfill generated the strongest leachate among the leachates analyzed during the study period as a result of the decomposition of the refuse which was accelerated by milling. The strip mine landfill generated a leachate of moderate strength. The permitted sanitary landfill also produced a leachate of moderate strength.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Solid Waste Landfill Baled Waste Leachate	Refuse Disposal Water Quality	13 B

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 284
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

DISCLAIMER

This report has been reviewed by the Municipal Environmental Research Laboratory, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communications link between the researcher and the user community.

This report summarizes and compares the positive advantages and negative characteristics of hillfills, balefills, millfills, strip mine landfills, and permitted sanitary landfills, then summarizes the results in terms of their individual environmental impacts over a period of one year on ground and surface water quality.

FRANCIS T. MAYO
Director
Municipal Environmental Research
Laboratory

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 297)
TYPING GUIDE SHEET

ABSTRACT

Water quality was monitored for one year at a hillfill, a balefill, a millfill, a strip mine landfill, and a permitted sanitary landfill to determine the impact of each on water quality. The leachate generated by the hillfill was the strongest during initial decomposition. However, during the study period, it was in the final stages of anaerobic degradation and therefore was of low strength. The hillfill had a severe, localized impact on ground-water quality due to the presence of a shallow water table and ground water mounding within the hillfill. It had no impact on adjacent surface water. The balefill produced a low strength leachate since this method of landfilling results in channeling of water through the landfill. The balefill's low strength and the 30-meter separation distance between the landfill and the water table resulted in minimal impact on ground-water quality. The millfill generated the strongest leachate among the leachates analyzed during the study period as a result of the decomposition of the refuse which was accelerated by milling. However, the millfill had a minimal, localized effect on ground-water resources. The strip mine landfill generated a leachate of moderate strength and exerted a moderate impact on ground- and surface water resources. The permitted sanitary landfill also produced a leachate of moderate strength. It exerted a minimal, localized impact on water quality due to the attenuative properties of the surficial materials and a significant depth to water.

This report was submitted in fulfillment of Contract No. 68-03-2620 by SMC-MARTIN under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period October 1977 to August 1980, and work was completed as of April 1981.

CONTENTS

Foreword iii
Abstract iv
Figures vi
Tables ix

1. Introduction 1
2. Conclusions 3
    Hillfill 4
    Balefill 5
    Millfill 5
    Strip mine landfill 6
    Permitted sanitary landfill 6
3. Recommendations 8
4. Study Design and Methods 10
    Site selection 10
    Design of monitoring systems 13
    Data interpretation 14
    Deviations from the study plan 15
5. Presentation of Five Solid Waste Disposal Methods 17
    Hillfill 17
    Balefill 48
    Millfill 78
    Strip mine landfill 104
    Permitted sanitary landfill 131
6. Comparison of the Five Solid Waste Disposal Methods with Standard Sanitary Landfill Methods 158
    Characteristics affecting the potential to pollute 158
    Advantages and disadvantages of the special types of landfills compared with a conventional permitted sanitary landfill 175
    Projection of the optimum applicability of the five types of landfills to various geographic areas 179

References 182

Appendices 186

FIGURES

Number Page

1 Map of the hillfill site 18
2 Graph of precipitation for the hillfill . . 20
3 Map of surficial geology at the hillfill site 22
4 Location of monitoring points at the hillfill site 25
5 Cross section of the hillfill site 32
6 Map showing the location of the line of cross section, AA' 33
7 Map of water table at the hillfill site . . 35
8 Bar graphs for alkalinity and acidity at the hillfill site 37
9 Bar graphs for TDS and TKN at the hillfill site 38
10 Bar graphs for COD and TOC at the hillfill site 39
11 Modified Stiff diagrams showing averaged results of chemical analyses at the hillfill site 43
12 Nitrogen index showing the ratio of organic nitrogen plus ammonia nitrogen (TKN) to nitrite plus nitrate nitrogen (NO2 + NO3) 45
13 Map of the balefill site 50
14 Graph of precipitation for the balefill . . 51
15 Map of surficial geology at the balefill site 54
16 Location of monitoring points at the balefill site 58
17 Cross section of the balefill site 63
18 Map showing the location of the line of cross section, AA' 64
19 Map of water table at the balefill site . . 66
20 Bar graphs for alkalinity and acidity at the balefill site 68
21 Bar Graphs for TDS and TKN at the balefill site 69
22 Bar graphs for COD and TOC at the balefill site 70

Number Page

23 Modified Stiff diagrams showing averaged results of chemical analyses at the balefill site 74
24 Nitrogen index showing the ratio of organic nitrogen plus ammonia nitrogen (TKN) to nitrite plus nitrate nitrogen (NO2 + NO3) 76
25 Map of the millfill site 79
26 Graph of precipitation for the millfill . . 81
27 Map of surficial geology at the millfill site 83
28 Location of monitoring points at the millfill site 87
29 Cross section of the millfill site 92
30 Map showing the location of the line of cross section, AA' 93
31 Map of water table at the millfill site . . 94
32 Bar Graphs for alkalinity and acidity at the millfill site 96
33 Bar graphs for TDS and TKN at the millfill site 97
34 Bar graphs for COD and TOC at the millfill site 98
35 Modified Stiff diagrams showing averaged results of chemical analyses at the millfill site 101
36 Nitrogen index showing the ratio of organic nitrogen plus ammonia nitrogen (TKN) to nitrite plus nitrate nitrogen (NO2 + NO3) 103
37 Map of the strip mine landfill site 106
38 Graph of precipitation for the strip mine landfill site 107
39 Typical stratigraphic column for Pennsylvanian-age coal measures 110
40 Location of monitoring points at the strip mine landfill site 113
41 Cross section of the strip mine landfill site 117
42 Map showing the location of the line of cross section, AA' 118
43 Map of water table at the strip mine landfill site 120
44 Bar graphs for alkalinity and acidity at the strip mine landfill site 122
45 Bar graphs for TDS and TKN at the strip mine landfill site 123
46 Bar graphs for COD and TOC at the strip mine landfill site 124

Number Page

47 Modified Stiff diagrams showing averaged results of chemical analyses at the strip mine landfill site 127

48 Nitrogen index showing the ratio of organic nitrogen plus ammonia nitrogen (TKN) to nitrite plus nitrate nitrogen (NO2 + NO3) 130

49 Map of permitted sanitary landfill site . . 132

50 Graph of precipitation for the permitted sanitary landfill 134

51 Map of surficial geology at the permitted sanitary landfill site 137

52 Location of monitoring points at the permitted sanitary landfill site 139

53 Cross section of the permitted sanitary landfill site 144

54 Map showing the location of the line of cross section, AA' 145

55 Map of water table at the permitted sanitary landfill site 146

56 Bar graphs for alkalinity and acidity at the permitted sanitary landfill site . . . 148

57 Bar graphs for TDS and TKN at the permitted sanitary landfill site 149

58 Bar graphs for COD and TOC at the permitted sanitary landfill site 150

59 Modified Stiff diagrams showing averaged results of chemical analyses at the permitted sanitary landfill site 153

60 Nitrogen index showing the ratio of organic nitrogen plus ammonia nitrogen (TKN) to nitrite plus nitrate nitrogen (NO2 + NO3) 154

61 Modified Stiff diagrams showing leachates from historical studies and the 1978-79 study 163

62 Graph of TDS concentrations with time of leachates from the hillfill, balefill, millfill, and strip mine landfill 164

63 Graph of COD concentrations with time of leachates from the hillfill, balefill, millfill, strip mine landfill, and permitted sanitary landfill 165

64 Graph of COD concentrations with time of leachate from the Boone County test cell 2D 166

TABLES

Number		Page
1	Alternative Methods of Solid Waste Disposal in Selected States East of the Mississippi River	11
2	Monthly Precipitation Data - Hillfill	21
3	Monitor Well Construction Details - Hillfill . .	26
4	Percentage of Separates by Weight for the Geologic Materials at the Hillfill	30
5	Monthly Precipitation Data - Balefill	52
6	Monitor Well Construction Details - Balefill . .	59
7	Percentage of Separates by Weight for the Geologic Materials at the Balefill	61
8	Monthly Precipitation Data - Millfill	82
9	Monitor Well Construction Details - Millfill . .	88
10	Percentage of Separates by Weight for the Geologic Materials at the Millfill	90
11	Monthly Precipitation Data - Strip Mine Landfill	108
12	Monitor Well Construction Details - Strip Mine Landfill	114
13	Monthly Precipitation Data - Permitted Sanitary Landfill	135
14	Monitor Well Construction Details - Permitted Sanitary Landfill	140
15	Percentage of Separates by Weight for the Geologic Materials at the Permitted Sanitary Landfill	142
16A	Characteristics Contributing to the Impact of Each Landfill on Ground and Surface Water . . .	159
16B	Characteristics Contributing to the Impact of Each Landfill on Ground and Surface Water . . .	160
17	Impact of Five Sites Shown by Representative Downgradient Wells	162

SECTION 1

INTRODUCTION

Solid waste generation and disposal represent a continuing environmental problem throughout the United States. Ninety percent of all municipal solid waste is disposed of on the land, at approximately 15,000 sites. Of these, approximately a third are permitted facilities. The Resource Conservation and Recovery Act (RCRA) will require the phasing out of open dumps during the 1980's, which will result in the disposal of increased volumes of waste in existing sanitary landfills and/or the opening of large landfills.

Suitable landfill sites must be used efficiently wherever they are available. Increasing emphasis will be given to placing more refuse in the site by increasing its height (i.e., hillfills), or by reducing waste volume (i.e., milling or baling). This increasing need for efficiency makes it necessary to evaluate and compare some alternatives to standard sanitary landfill methods with respect to their impacts on the environment (surface and ground-water resources in particular).

This study compares and evaluates five alternatives to standard sanitary landfill methods: millfill, balefill, hillfill, and strip mine landfill. The relative environmental impacts of these methods on water resources are determined along with site characteristics that contriubte to or prevent pollution. Projections are also made for the probable usefulness of each method in other geographic areas. Sites east of the Mississippi River were chosen on the basis of selection criteria (see Section 4) established during the initial stages of the study. Field evaluations were made at each site to confirm site conditions.

At each of the sites, wells were drilled to collect data on the direction of ground-water flow and ground-water quality. Analytical parameters were selected on the basis of previously existing data available at each site. Monitoring involved the collection of water samples from selected sampling points on a quarterly basis for a year. Meteorologic and hydrologic data were also collected to aid in the interpretation of water quality data.

These data were then examined to determine the environmental impact of each waste disposal site. On the basis of the environmental impacts and a consideration of site characteristics, waste disposal methods were compared and contrasted to identify the suitability of each for use in various geographic areas.

SECTION 2

CONCLUSIONS

Virtually all unlined solid waste disposal facilities impact negatively on ground and surface water resources to some extent. The factors which effectively mitigate the impacts of waste disposal facilities include methods of operation, site suitability (in particular, depth to ground water) and the engineering design for a particular facility. Based on the site selection process for the present study, the conventional permitted sanitary landfill is the most common method of waste disposal. The next most common method is the use of strip mine landfills which are frequently found in Pennsylvania, Ohio, and Illinois. Millfills, balefills, and hillfills are relatively uncommon in comparison to permitted sanitary landfills and coal strip mine landfills.

This study is based on a selection of state-of-the-art landfills which were designed to minimize adverse environmental impacts. All of the landfills investigated performed fairly well and exerted only minimal, localized adverse impacts on the surrounding ground and surface water; an exception to this rule is the hillfill. In general, contamination from each site was not significant beyond the property boundary. The effects of each landfill could be observed in comparison with background water quality, but downgradient water quality was frequently within drinking water standards.

Many differences in the impacts of the five landfills resulting from the method of landfilling were distinguished during this study; however, there were also many differences caused by variations among site conditions, ages, and the amount of refuse emplaced in each landfill. The two primary factors that are direct functions of the method of landfilling are the potential volume of leachate and the strength of that leachate.

If it were possible to examine the five methods of landfilling using a uniform quantity of solid waste, on the basis of this study, certain results could be anticipated. A balefill should have the lowest potential volume of leachate because of the reduced area of the landfill base; its leachate should be the least concentrated. A millfill, again because the area of the base of the landfill is reduced, ought to have the next lowest potential volume of leachate but it should have the strongest initial leachate concentrations. A hillfill, since infiltration is reduced by steep slopes and since the basal area of the landfill is reduced by building upwards, also should have a relatively low potential volume of leachate which ought to be of moderate to considerable strength. Both the permitted sanitary and strip mine methods of landfilling ought not be expected to reduce the potential volume of leachate (unless a strip mine should have a highwall of such dimension that it would produce effects similar to those of a hillfill) and leachates should have moderate to strong concentrations.

The following conclusions regarding each of the five methods of operations investigated in the present study are offered.

HILLFILL

Hillfilling is an effective method of reducing the areal extent of a landfill. It increases the volume of waste per unit area through an increase in height and decreases the potential volume of leachate because of steep slopes. Among the sites studied, the hillfill had the greatest potential volume of leachate and the leachate generated by the hillfill (1969 data) was the strongest. The landfill, during 1978 and 1979, was in the final stages of anaerobic degradation and so generated a leachate of low strength at that time.

The hillfill had the most severe environmental impact on ground-water resources but had no impact on adjacent surface water. Its impact was localized because of a minimal ground-water gradient and attenuation attributable to the presence of clay at the site. The leachate generated by the hillfill has not contaminated the bedrock aquifer but has moved downward in the shallow aquifer under decreasing aquifer head. The primary cause of the degradation of the ground-water resources in the vicinity of the hillfill site was the shallow depth to water and the ground-water mounding that occurred within the hill. Leachate is impounded within the hill as a result of the construction of a relatively impermeable clay base. Because of the head of leachate within the hillfill, it is possible that leachate migrates outward from the base of the landfill through ruptures in the clay.

BALEFILL

Baling is the most effective method of volume reduction; it results in the highest density of refuse. It effectively reduces the area required for landfilling and minimizes the amount of cover material required. Among the five sites investigated, the balefill contained the greatest weight of refuse and had the second highest potential leachate volume.

The leachate generated by the balefill was of low strength; in fact, it had the lowest concentration of any of the leachates generated among the five landfills studied. This is attributable to the high density of the refuse and the rapid channeling of water through the bales. The site has had a minimal localized impact on ground-water resources. With the exception of organics, all parameters indicate a lower level of contamination to the ground water when compared with the permitted sanitary landfill. The minimal impact of the balefill can be attributed to a combination of low strength leachate and in excess of 30 m (100 ft) of separation between the base of the landfill and the water table.

MILLFILL

Millfilling achieves a high density of refuse and is an effective volume reduction method which minimizes the area required for landfilling and, although such was not the practice at the site studied, does not require daily cover.

The leachate generated by the millfill, based on the one sample that could be collected, was the strongest among the leachates analyzed during the study period. The increased surface area of milled refuse accelerates the rate of its physical and chemical decomposition and so leachate is produced more quickly and is characteristically of greater strength at a millfill. The millfill leachate is comparable to the initial leachate concentration generated by the hillfill and to the leachate generated by the Boone County test cell. It has had a minimal localized effect upon ground-water resources. Apparently, it has had comparably less impact than the permitted sanitary landfill which, in part, may be due to the distance between the fill and the monitor wells. The millfill has not significantly polluted the aquifer and the water supply at the landfill remains potable. Because daily cover is applied, the millfill examined in this study appears to behave more similarly to a permitted sanitary landfill than to the classic millfill which is uncovered.

STRIP MINE LANDFILL

Of the five sites investigated during the course of this study, the strip mine landfill had the lowest refuse density. This method of landfilling does, however, make good use of available space and, depending upon the height of the highwall, allows for an increased volume of refuse to be placed on a relatively limited base area. The leachate generated by the strip mine landfill was of moderate strength, lower in concentration than the leachate initially generated by the hillfill or the millfill. The strip mine landfill leachate exerted a moderate impact on ground-water and surface water resources in the vicinity of the site. Despite the fact that the strip mine landfill had the greatest potential for contamination because attenuative soils generally are not present, the site did not have a significantly adverse impact on the ground water because of several factors: a substantial separation exists between the base of the landfill and the water table; the base of the landfill was backfilled with spoil material prior to initiating landfilling operations; and the slopes at the site increase the amount of runoff and decrease infiltration because the completed areas of the landfill have been restored to approximate original contour.

PERMITTED SANITARY LANDFILL

The permitted sanitary landfill had the least amount of refuse and the lowest potential volume of leachate among the sites investigated in the present study. It exerted a minimal localized impact on the ground and surface water resources in its vicinity. Immediately beneath and adjacent to the landfill, degradation of ground water was noticeable; however, there was no contamination to adjacent surface water. The minimal impact of the permitted sanitary landfill leachate on ground water may be attributed to a combination of the attenuative properties of the surficial materials at the site and a significant depth to water.

Based on the environmental impacts of each of the five sites studied, it appears that all five methods of landfilling are environmentally acceptable methods of operation providing site characteristics allow for the natural renovation of leachate. It must be emphasized that site characteristics, particularly depth to water, are crucial to the ultimate impact of any landfill, regardless of the method of operation. The results of this study suggest that balefilling and millfilling offer significant benefits when these methods are used under optimal site specific circumstances. However, because of their capital cost, a relatively dense level of population is required to support the associated processing facilities.

SECTION 3

RECOMMENDATIONS

The following recommendations are offered on the basis of this study of five landfills employing special landfilling methods:

o The monitoring of both ground and surface waters should continue at each site.

o The leachate within the hillfill should be removed in order to reduce its head and thus reduce its flow into the surrounding ground water.

o Demolition wastes should be accepted at the balefill (as at present) and should be used to obtain a final grade that is in accordance with plans for its use when completed. During continued monitoring, particular attention should be directed to the organic content of the ground water at MP #2.

o At the millfill, precautions should be taken to prevent leachate breakouts. When the millfill is closed, there should be close adherence to the final grading plans to ensure maximum surface water runoff and avoid ponding.

o Those portions of the strip pit that have not yet received refuse should be lined, at both the base and highwall, with 0.9 to 1.5 m (3-5 ft) of clean, relatively impermeable fill material in order to prevent the migration of leachate along bedding planes. The erosion rills present on completed portions of the strip mine landfill should be repaired to eliminate surface leachate breakouts and completed portions should be revegetated to obtain a denser vegetative cover.

o The permitted sanitary landfill should be regraded to increase surface water runoff.

o Waste disposal at the millfill and the strip mine landfill (the only two active landfills) should continue to be confined to mixed municipal solid waste.

o It is strongly recommended that careful consideration be given to the siting of all types of landfills with particular emphasis on hydrogeologic conditions. Many of the differences among special landfill types that are caused by the method of landfilling have been identified during this study. However, there are significant variations in site conditions among the landfills examined including geographic, climatic, and hydrogeologic variations which affected the impacts of the five landfills on the environment. Because of these variables and considering the differences among the landfills including age, area, and amount and type of refuse, it is difficult to make direct comparisons about the environmental impacts each method of landfilling exerts. It is therefore recommended that, in order to minimize the affects of these variations and to derive additional information about the relative environmental impacts of the methods employed at special types of landfills, a controlled study be performed. This might best be accomplished by constructing, within a certain area, four field-scale test cells; one containing baled refuse, one milled, one unprocessed, and one to be hillfilled; each cell should be hydrologically isolated. Background data should be obtained including complete climatic records, specific hydrologic characteristics, and precise subsurface information.

Construction methods should be as uniform as possible and the refuse emplaced in each of the cells should be from the same source to minimize variability among the cells. Leachate should be collected from each cell and analyzed periodically. In addition, monitoring should include samples from a series of monitoring wells surrounding each cell, preferably located in sets with increasing distance from the cell so that attenuation, dilution, and dispersion properties can be defined. Soil moisture, temperature, gas production, and settlement should also be monitored. Monitoring should take place from the initial emplacement of refuse in the cells through the final stages of degradation in order to determine the relative strengths, composition, and trends of leachates. This type of study would eliminate site variations and allow a more direct comparison among four special methods of landfilling.

SECTION 4

STUDY DESIGN AND METHODS

The design of the study included establishing site selection criteria, developing methods of site selection, and designing monitoring procedures (including methods of well drilling, sampling, and chemical analyses). The basis for the design of many of these elements in the study has been previously determined by the U.S. Environmental Protection Agency (EPA).

SITE SELECTION

The process of site selection for this study was initiated with a survey of known sites using different methods of waste disposal (hillfill, balefill, millfill, and coal strip mine landfill) located east of the Mississippi River. The survey identified 17 hillfills, 15 balefills, 23 millfills, and 253 coal strip mine landfills (see Table 1). These data were compiled from information gained from EPA files, State regulatory agencies and solid waste authorities, major waste management corporations, technical publications and journals, and landfill owners and operators. During the survey, information was obtained about the location, ownership, and size of the fill. Facts were collated about the following specifications: Rate of filling, operational procedures, design parameters, age, ground and surface water monitoring procedures, presence or absence of leachate discharges, availability of analytical results from monitoring, availability of reports, and comments about regulatory involvement.

Each site was evaluated on the basis of selection criteria encompassing the many variables (depth-to-water, geology, hydrology, refuse-processing, site preparation) which existed among the surveyed facilities. Site selection criteria established prior to initiating the study included:

1. Availability of detailed engineering and scientific reports.
2. Availability of background analytical data.
3. Existence of monitor wells.

TABLE 1. ALTERNATIVE METHODS OF SOLID WASTE DISPOSAL IN SELECTED STATES EAST OF THE MISSISSIPPI RIVER

State	Hillfill	Balefill	Millfill	Coal strip mine fill
Alabama	0	2	0	0
Connecticut	0	0	0	0
Delaware	0	0	1	0
Florida	1	0	3	0
Georgia	0	2	2	0
Illinois	6	0	1	40
Indiana	3	0	0	6
Kentucky	0	0	0	15
Louisiana	0	0	2	0
Maine	0	1	1	0
Maryland	0	0	1	2
Massachusetts	0	1	1	0
Michigan	1	0	0	0
Minnesota	2	1	0	0
Mississippi	0	0	0	0
Missouri	0	0	0	6
New Hampshire	0	0	0	0
New Jersey	0	1	1	0
New York	0	6	1	0
North Carolina	0	0	1	0
Ohio	0	1	2	56
Pennsylvania	1	0	0	120
Rhode Island	0	0	0	0
South Carolina	1	0	4	0
Tennessee	0	0	0	2
Vermont	0	0	0	0
Virginia	1	0	0	0
West Virginia	0	0	0	6
Wisconsin	1	0	2	0
Total	17	15	23	253

Supplementary site selection criteria added later included:

1. Availability of the site for study.
2. Accessibility of the site.
3. Status of litigation, if any.
4. Overall representative nature of the site.
5. The sites must be unlined.
6. Refuse must have reached field capacity and be generating leachate.
7. The sites must not accept large quantities of industrial wastes.
8. All sites must have similar climatology.

Data gained through the survey was compared with the site selection criteria and was reduced to a matrix which identified the principal characteristics of each site as they related to the site selection criteria. Facilities which appeared to meet the site selection criteria were thus identified, reducing the list of potential candidate sites for study. The operator of each of these sites was contacted in order to confirm the data obtained during the initial survey. At this time, details of the project were discussed with the site owners and a formal request was made for their cooperation in conducting the study.

It became apparent that the cooperation of landfill owners, whether public or private, was to become a major problem. Their lack of cooperation stemmed mainly from their concern about legal liability. Another problem that arose during discussions with site owners pertained to the lack of monitoring and detailed background data available. It is unfortunate that the owners who had the most data pertaining to their site were the least cooperative; several refused to discuss their operations at all.

In order to gain the cooperation of site owners, it was agreed that site names and locations would be held in confidence. For this reason, sites will be referred to only by the method of landfilling employed and the general location.

Five sites were identified as principal candidates for study and field evaluations were made at each to confirm existing data, assess the physical setting, and conduct geologic and hydrologic evaluations. Meteorological data, additional data pertaining to operational history, and data from regulatory agencies was collected during the field evaluation. After the initial evaluation, it was found that several of the five principal candidate sites did not meet the criteria; additional sites had to be selected.

The evaluation revealed that few sites were well monitored. Of the 17 balefills identified east of the Mississippi River, none had ground-water monitoring systems. Coal strip mine landfills were either poorly monitored or accepted quantities of industrial waste sufficient to render comparisons with other sites useless. Millfills tended to use daily cover in their operations and were commonly well monitored. It was ultimately decided that the final sites selected would be those which best met the site selection criteria and were representative of sites in similar settings. In this way, a meaningful comparison among various sites could be effected. Data gathered during the field evaluation and other background data collected during earlier stages of the project was evaluated in order to determine the necessity for additional monitoring.

DESIGN OF MONITORING SYSTEMS

Existing hydrologic and analytical data were reviewed to define the direction of ground-water flow and contaminant enclaves. This information was used to determine whether additional monitor wells would be necessary to refine the capabilities of the monitoring system. All sites except the sanitary landfill required the installation of additional wells. The sanitary landfill had been studied previously and had an adequate network of wells. Monitoring wells were located at each of the other sites to define ground-water and contaminant movement. Drilling methods (see Section 3) were developed for each site based on the prevailing geologic conditions. Air rotary drilling was employed at the millfill and coal strip mine landfill. Soil boring was used at the hillfill and mud rotary drilling at the balefill. All available well logs are shown in Appendix A.

In order to gain additional information on the attenuation properties of each site, particle size analyses were conducted on samples obtained during well drilling for the four sites located on unconsolidated material: the hillfill, balefill, millfill, and permitted sanitary landfill. Samples were tested in accordance with the American Society for Testing and Materials (ASTM) D 422. Grain size distribution curves for each sample tested are included in Appendix B. A list of percentages of soil separates (clay, silt, sand, coarse fragments) based on the USDA size limits are presented in Tables 4, 7, 10 and 15.

EPA had determined chemical analytical parameters prior to the initiation of the study. They were to be limited to three anions, three cations, three nutrients, and three demand tests. After studying the historical data for each site, it was determined that alkalinity, acidity, sulfate, chlorides, total organic carbon, chemical oxygen demand, total solids, total dissolved solids, nitrate nitrogen, ammonia nitrogen, phosphates, total Kjeldahl nitrogen, copper, iron, manganese, sodium, lead, and zinc would be analyzed for each sample collected. In addition, pH, temperature, and specific conductivity would be measured in the field for each sampling point.

At each site, samples were collected after the well(s) had been cleared to assure that representative samples were obtained. Depth to water was measured prior to clearing (see Appendix C). A submersible pump was used at the permitted sanitary landfill and the coal strip mine landfill and a diaphragm pump was used at the millfill. Bailing was the method used to clear the wells at the hillfill because of their 2-inch diameter and depth-to-water of more than 30 feet. A combination of submersible pumps and bailing was necessary at the balefill because of depth-to-water and technical difficulties in employing the submersible pump during the winter months. After samples had been obtained and field measurements of pH, temperature, and specific conductivity had been taken, the samples were filtered through No. 40 filter paper using a Buchner filtering funnel and flask. Samples were preserved in accordance with EPA standard methods, iced, and shipped by air to the analytical laboratory for analysis. At the laboratory, EPA standard analytical procedures were followed.

DATA INTERPRETATION

The initial process of data interpretation involved reviewing historical (previously existing) analytical data for each site selected. These data were entered in a computer for effective management. Data collected during the study period was similarly entered. Output was organized in such a manner that the analytical result or parameter could be displayed for each monitoring point for each sampling date. A summary of mean results obtained, number of observations, and standard deviation is provided (see Appendix D for historical results and Appendix E for results obtained during this study).

After reviewing the data for each site, methods of display were developed to illustrate the results obtained in a manner that allows clear concise interpretation and comparison. A series of bar graphs (histograms), Stiff diagrams, and a nitrogen index have been selected for this purpose.

Bar graphs have been utilized to illustrate the mean concentration of the general indicators of water quality including alkalinity, acidity, total dissolved solids (TDS), total Kjeldahl nitrogen (TKN), chemical oxygen demand (COD), and total organic carbon (TOC). The relative height of each bar makes comparison among the monitoring points readily apparent for similar parameters.

To further illustrate the effect of the landfills on ground and surface water and to illustrate water quality variations between monitoring points, Stiff diagrams have been constructed using the average concentrations of sodium, iron, manganese, zinc, chloride, sulfate, nitrate, and phosphate. The means were calculated using data from the current study period only. Because of the large range in milliequivalents of ions, a semi-logarithmic scale has been used.

Stiff diagrams are a graphical procedure designed to display analyses. They provide a distinctive method for showing water composition and a means for the comparison of analyses with each other, emphasizing relative differences and similarities. Concentrations of cations and anions are plotted on parallel horizontal scales and the points are connected to produce irregular polygonal shapes. The width of the shape is an approximate indication of the total ionic content.

The nitrogen index has been used to delineate redox (oxidation and reduction) zones in the ground water and to determine the location of reducing fronts as leachate migrates from the landfill. The index is a ratio of organic nitrogen and ammonia nitrogen (TKN) to nitrite and nitrate nitrogen (NO_2 + NO_3). The ratios were calculated using mean values for the study period. A small number (0.01) indicates the absence of reduced nitrogen and, therefore, oxidizing conditions; a large number (greater than 100) indicates a concentration the landfill. The index is a ratio of organic nitrogen and ammonia nitrogen (TKN + NH3) to nitrite and nitrate nitrogen (NO2 + NO3). The ratios were calculated using mean values for the study period. A small number (0.01) indicates the absence of reduced nitrogen and, therefore, oxidizing conditions; a large number (greater than 100) indicates a concentration of ammonia and nitrogen-containing organic compounds which exist under reducing conditions.

DEVIATIONS FROM THE STUDY PLAN

Several deviations from the study plan resulted from the extended period required for the site selection process necessitated by the lack of cooperation from site owners. Neither the balefill nor the strip mine landfill had monitoring wells prior to this study. They were selected since monitoring had not been instituted at any of the balefills east of the Mississippi River and comprehensive ground-water monitoring had not been accomplished at any coal strip mine landfill which did not accept substantial quantities of industrial waste and would agree to cooperate during the study.

There were two additional areas of deviation from the original study plan. Resistivity surveys could not be conducted after the site selection process had extended into the winter months. Well drilling was therefore undertaken immediately after site selection and, since the principal rationale for conducting electrical resistivity surveys had been to aid in locating the monitor wells, such studies were deleted from the project. Furthermore, the suction lysimeters originally proposed for this study could not be used since EPA policy discourages the installation of lysimeters requiring drilling through refuse. Lysimeters could not be installed at the coal strip mine landfill or at the permitted sanitary landfill because of shallow bedrock.

SECTION FIVE

PRESENTATION OF FIVE SOLID WASTE DISPOSAL METHODS

The environmental impact of each of the five landfill methods is evaluated by describing the topographic position, climate, geology and soils, landfill operation, monitoring network, particle size analyses, hydrogeology, and the results of chemical analyses.

HILLFILL

A need arose in a rapidly developing County for a site to dispose of municipal solid waste; the hillfill, an above-grade landfill, was designed in order to make the best possible use of the limited available space. It was developed as part of a master plan for a large recreational complex. Because of its height, the completed hill serves as a sledding and ski slope.

Topographic Position

The hillfill lies within the Central Lowlands physiographic province. The preglacial topography was modified by glacial ice into its present form of low, broad moraines characteristically forming flat to gently rolling topography. The hill created by the landfill covers a 16-ha (40-ac) base and rises 46 m (150 ft) above the surrounding landscape.

Drainage for the area is poorly integrated with numerous swamps and marshy areas. The primary drainage pattern for the surrounding area is formed by a southerly flowing river located approximately 610 m (2000 ft) west of the fill site (see Figure 1). The river is fed by a perennial tributary which flows through a swampy area located approximately 0.8 km (0.5 mile) north of the hillfill. The intersection of the river and the tributary occurs slightly south of the hillfill. There are three man-made ground-water-fed lakes located adjacent to the hillfill lying to the south and east. Vegetation in the area consists of woodland, marsh, and meadow grasses. The hillfill has been revegetated with grasses.

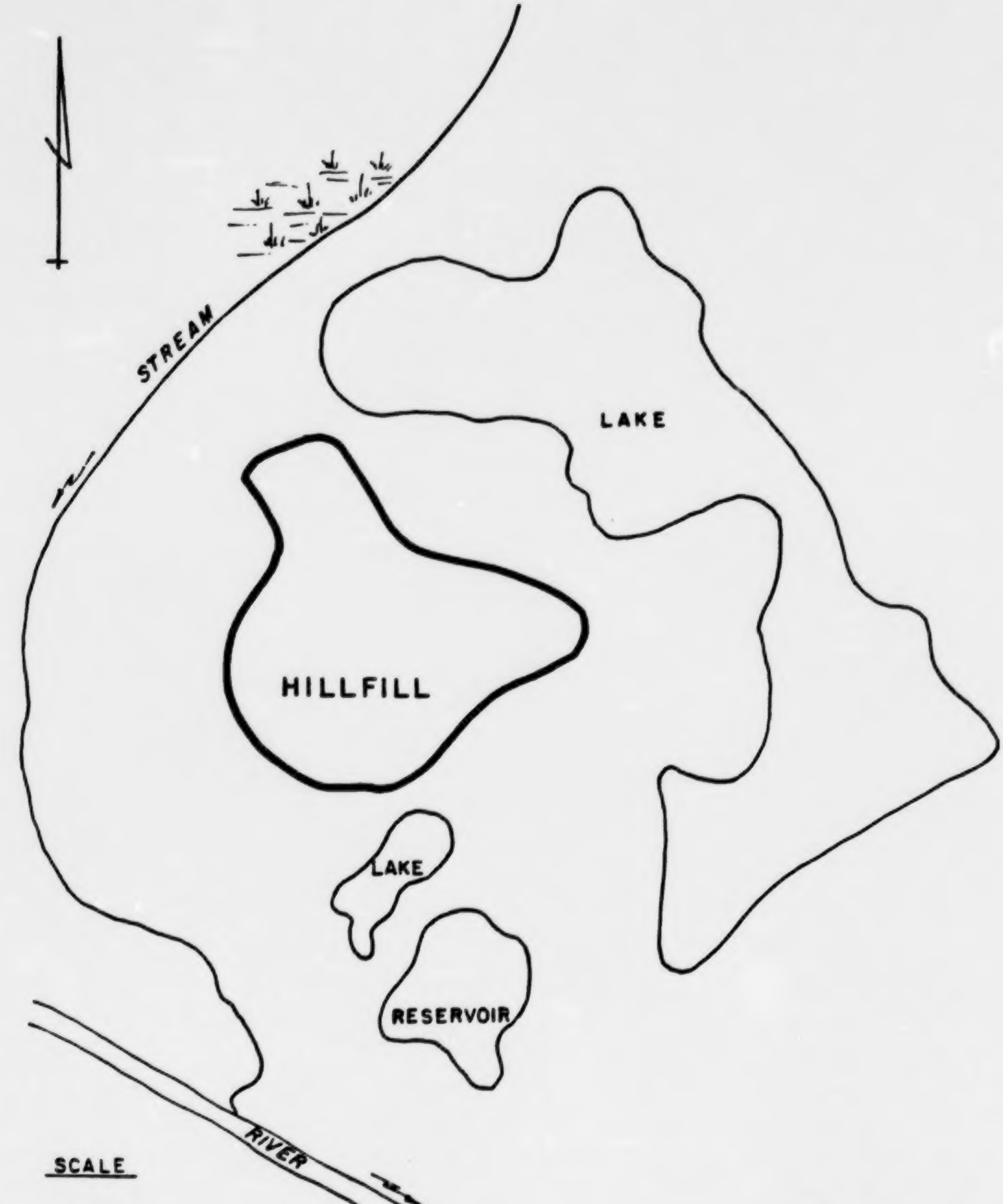

STREAM
LAKE
HILLFILL
LAKE
RESERVOIR
RIVER
SCALE
305 m
1000 FT.

Figure 1. Map of the hillfill site.

Climate

The climate at the hillfill is humid continental and is characterized by cold, moderately dry winters and warm to hot, wet summers. A large lake lies 64 km (40 miles) to the east of the site but is considered to have only a minimal effect on the climate of the study area.

Based on data compiled by the U.S. Weather Bureau at a nearby weather station for a 30-year period of record, the mean annual precipitation for the hillfill area is 86.49 cm (34.05 in). It varies throughout the year from a normal low of 3.78 cm (1.49 in) in February to a normal high of 10.77 cm (4.24 in) in June (see Figure 2 and Table 2). April through September are the wettest months of the year accounting for 60 percent of annual precipitation. The average snowfall per year is 81.79 cm (32.20 in). Precipitation during the one-year study period was 27.23 cm (10.72 in) above normal. The months of October 1978, February 1979, May 1979, and July 1979 had slightly below normal precipitation; all other months were above normal. Greater than normal snowfall occurred during January 1979 with a total of 70.10 cm (27.60 in) which is only 16.38 cm (6.45 in) less than the total normal yearly average.

The mean annual temperature for the hillfill area is 9.3 C (48.9 F) with a normal low of -5.4 C (22.2 F) occurring in January and a normal high of 22.5 C (72.9 F) in July.

Geology and Soils

The hillfill is underlain by bedrock of Silurian age covered by a mantle of glacial and post-glacial sediments. The bedrock of the area is composed of Silurian dolomites of the Alexandrian and Niagaran Series. The Niagaran dolomites underlying the hillfill site are subdivided into the Joliet, Waukesha, and Racine Formations which range from clean to highly silty, argillaceous, cherty dolomites. Bedrock dips gently to the east and southeast at approximately 2 m/km (10 ft/mile). The Niagaran Series dolomites are the most productive aquifers in the area.

Bedrock is overlaid by approximately 24 m (80 ft) of unconsolidated glacial deposits of the Wisconsin Stage (Pleistocene Epoch). They are composed primarily of tills and both glaciofluvial and glaciolacustrine deposits. Most of the site is underlain by the Henry Formation (see Figure 3); it consists of sand and gravel outwash (well sorted, glaciofluvial deposits) and is frequently covered by a thin layer of loess (windblown silt deposited after the Wisconsin glacial advance). Beneath the site, outwash deposits range from greater than 12 m (40 ft) to 8.5 m (28 ft), and are

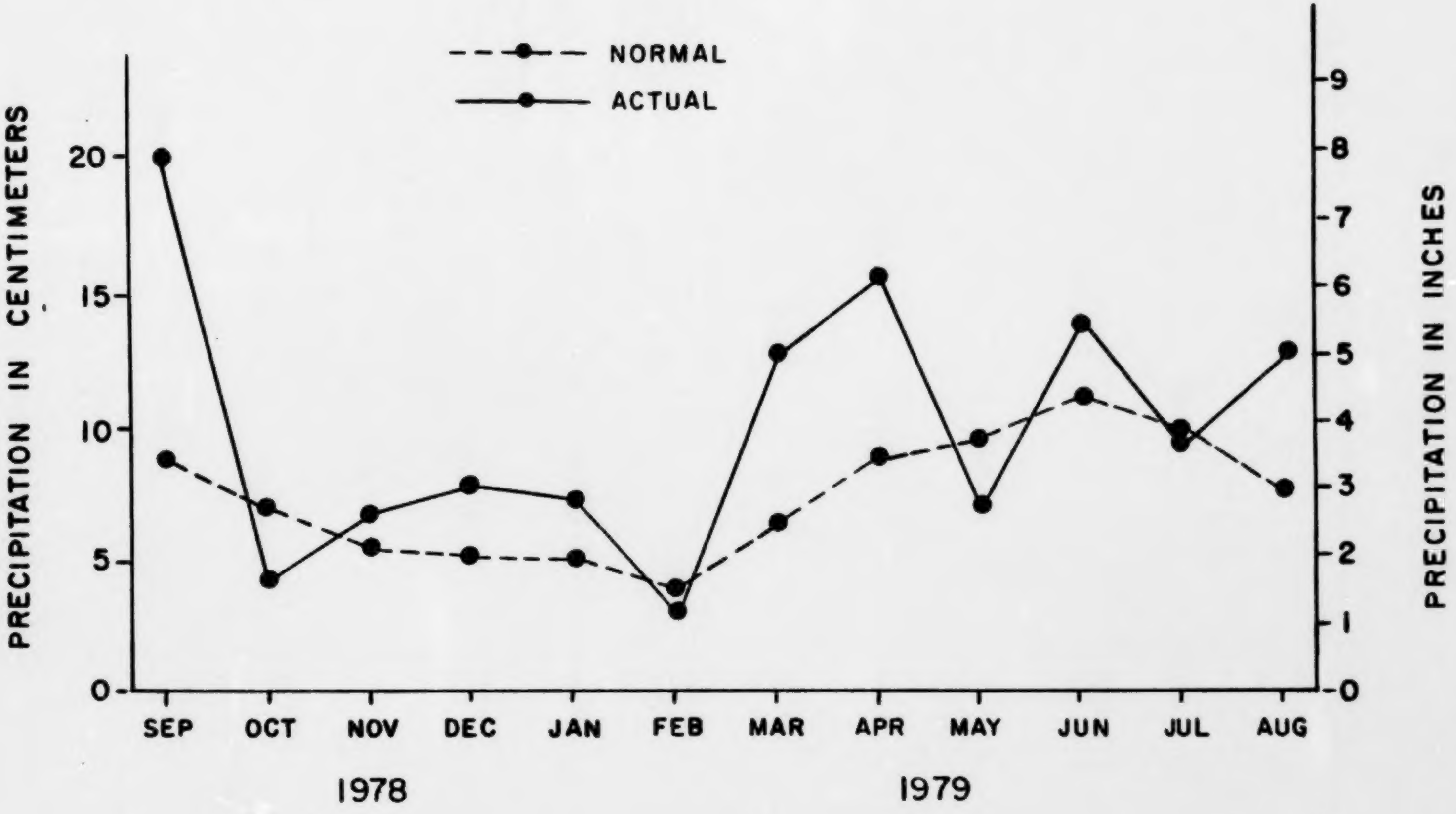


Figure 2. Graph of precipitation for the hillfill.

TABLE 2. MONTHLY PRECIPITATION DATA[a] - HILLFILL

Date	Normal	Actual	Departure from normal
9/78	8.81 (3.47)	20.07 (7.90)	11.25 (4.43)
10/78	6.71 (2.64)	4.17 (1.64)	- 2.54 (- 1.00)
11/78	5.46 (2.15)	6.55 (2.58)	1.09 (0.43)
12/78	5.08 (2.00)	7.95 (3.13)	2.87 (1.13)
1/79	4.78 (1.88)	6.91 (2.72)	2.13 (0.84)
2/79	3.78 (1.49)	2.90 (1.14)	- 0.89 (- 0.35)
3/79	6.17 (2.43)	12.45 (4.90)	6.27 (2.47)
4/79	8.74 (3.44)	15.39 (6.06)	6.65 (2.62)
5/79	9.07 (3.57)	6.60 (2.60)	- 2.46 (- 0.97)
6/79	10.77 (4.24)	13.56 (5.34)	2.97 (1.10)
7/79	9.60 (3.78)	9.35 (3.68)	- 0.25 (- 0.10)
8/79	7.52 (2.96)	12.60 (4.96)	5.08 (2.00)
TOTAL	86.49 (34.05)	118.50 (46.65)	32.17 (12.60)

[a] Measurements in cm (in)

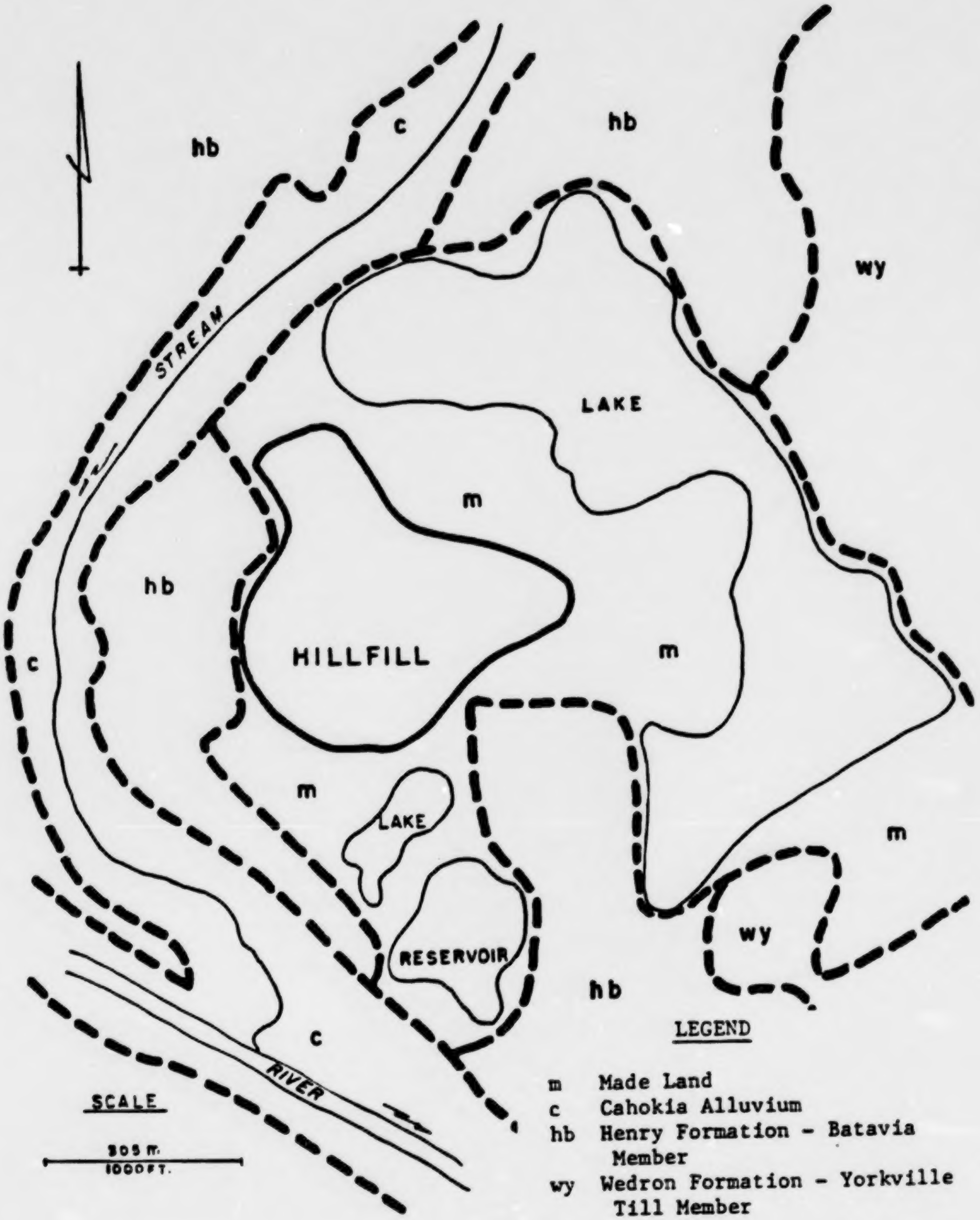

hb
c
hb
wy
STREAM
LAKE
m
hb
HILLFILL
m
c
m
LAKE
m
wy
RESERVOIR
hb
c
RIVER
SCALE
305 m.
1000 FT.
LEGEND
m Made Land
c Cahokia Alluvium
hb Henry Formation - Batavia Member
wy Wedron Formation - Yorkville Till Member

Figure 3. Map of surficial geology at the hillfill site.

generally thicker toward the west. Underlying the Henry Formation and exposed in the extreme eastern portion of the site is the Wedron Formation, also of the Wisconsin Stage. This formation is composed of dark grey to greenish-grey, very clayey till which contains abundant pebbles and is overlain in some places by extensive glaciolacustrine deposits.

The areas mapped as Made Land include the hillfill and the three lakes; a thick layer of gravel (the Henry Formation) and an underlying layer of impermeable clay (part of the Wedron Formation) were excavated to form the lakes. The clay was stockpiled and later used to construct the cells of the hillfill. Along the stream and river are deposits of the Cahokia Alluvium, flood-plain and channel deposits of present rivers and streams composed of silt and sand, some gravel and organics.

Soils in the area of the hillfill were mapped by the USDA Soil Conservation Service after filling operations were begun. The original soils at the hillfill site were stripped during the site preparation. Therefore, the soils underlying the hillfill have been mapped as urban land or miscellaneous land.

Soils east of the hillfill have a parent material of glacial till while other soils in the area have parent materials of alluvium, outwash and loess. Soil series with parent materials of loess and outwash are the Casco loam, Fox silt loam, Kane silt loam and Barrington silt loam. These soils are moderately well to well drained and moderately permeable. The soil series found near the stream with a parent material of alluvium is the Sawmill silty clay loam. This soil is poorly drained and moderately to slowly permeable. East of the hillfill, the predominant glacial till-derived soil is the Morley silt loam. It is moderately well to well drained and has a slowly permeable subsoil.

Landfill Operations

The hillfill was operated from November 1965 to October 1971 on a 485-ha (1200-A) site owned by the County. Final cover and grading were completed during the autumn of 1973. The facility served a population of 500,000 and received mixed municipal refuse at a rate of 530 to 1900 m^3 (700-2500 yd^3) per day. No hazardous industrial wastes were accepted.

Nearly 760,000 m^3 (1 million yd^3) of clay cover material and an approximately equal amount of compacted refuse were used to construct a hill 46 m (150 ft) in height and covering a 16-ha (40-ac) base. This results in an average volume of refuse per area of 47,500 m^3/ha (25,000 yd^3/ac).

Construction of the hill was developed in 0.8 to 1.6 ha (2-4 ac) cells. The floor of the base cells was leveled and covered with 0.6 m (2 ft) of impervious clay. This raised the base of the hillfill 3.7 m (12 ft) above the water table. Berms of clay from 4.6 to 6.1 m (15-20 ft) in thickness were constructed on this base to form the lateral boundaries of each cell. Refuse was deposited in the cells and compacted in lifts from 0.9 to 1.2 m (3-4 ft) in height, and covered daily. The final height of each cell ranges from 1.5 to 3.1 m (5-10 ft). Cells were constructed in layers until the desired height and shape of the hill were obtained. Upon completion of the fill operation, 3 m (10 ft) of final cover was placed over the berms and 15 cm (6 in) of top soil was applied. The hill was seeded with a mixture of grasses.

During the study period, no leachate seeps or vectors were observed; however, leachate breakouts had been reported in the past. There was a strong odor of gas escaping from the leachate wells and some evidence of erosion on the northwestern slopes of the hill which are the steepest at the site. The County maintains the cover and vegetation at the site on a regular basis.

Monitoring Network

Eleven wells were used to monitor the hillfill during the study period (see Figure 4, Table 3, and Appendix A). Five of these were previously existing observation wells (MP #1, #3, #4, #5, #9); one was a previously existing monitoring well (MP #2); three were water supply wells (MP #11, #13, and #15) and two were new monitoring wells drilled for this study (MP #10 and #12).

MP #2 is a leachate monitoring well located on the eastern slope of the hill. It had been installed so that samples of the leachate generated by the hillfill could be obtained. It was completed into the refuse to a depth of 24.4 m (80.0 ft) and was constructed with 15.24 cm (6.00 in) steel casing. The lowermost 16.5 m (54.0 ft) of casing was slotted to permit leachate to enter the well and a vent was installed to facilitate the escape of gases.

MP #1, #3, #4, #5, #9 were all drilled by auger and completed with 3.18 cm (1.25 in) PVC casing. The final 0.3 m (1.0 ft) of casing was perforated to permit the entry of ground water. These wells were originally installed as piezometers but, for the purposes of this study, they were used to monitor both water levels and water quality.

MP #1, #3, #4 form a well-nest near the eastern toe of the fill. MP #1 was completed at 19.0 m (62.4 ft) in clay

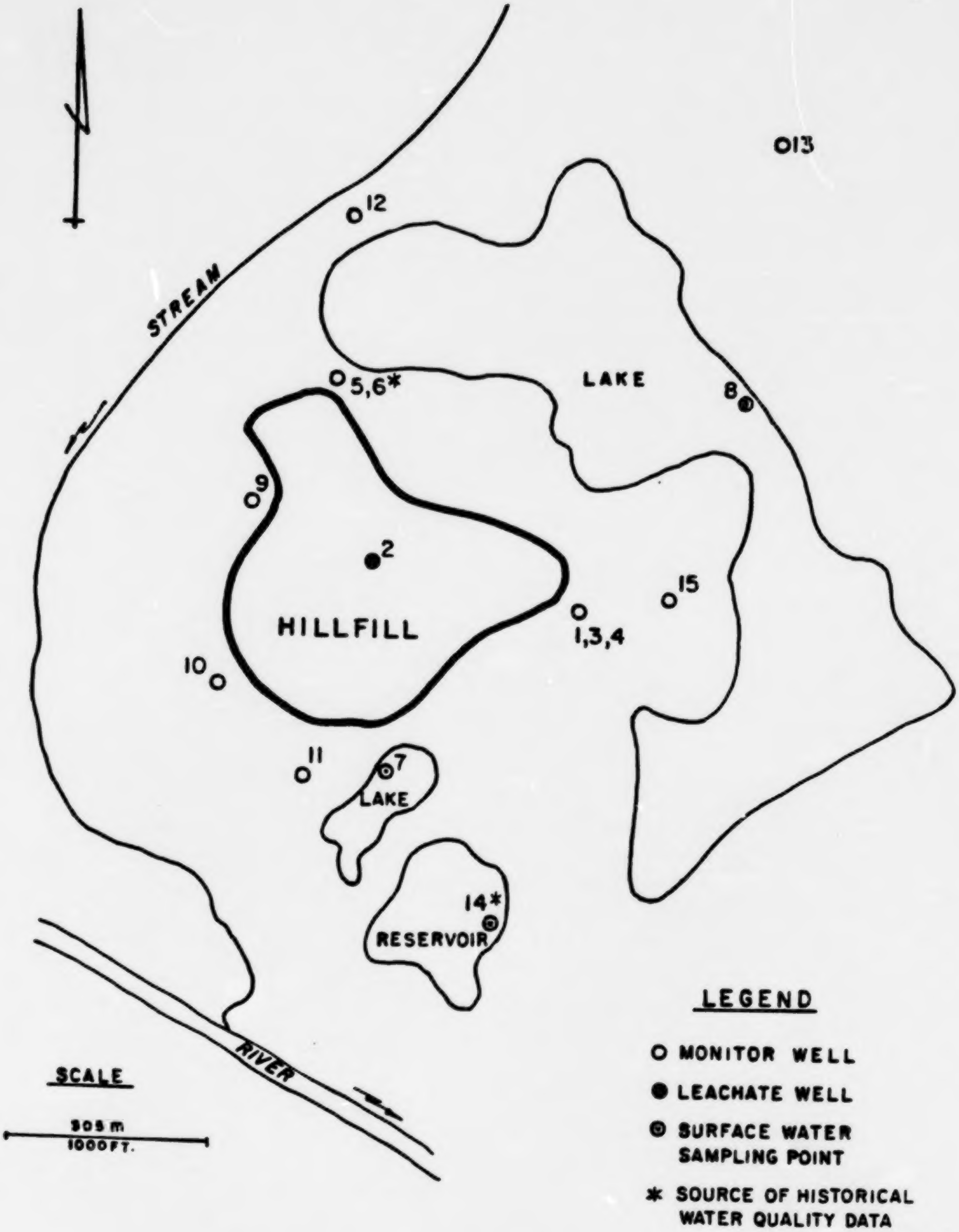

O13
O12
STREAM
O5,6*
LAKE
8
9
2
HILLFILL
15
1,3,4
10
11
7
LAKE
14*
RESERVOIR
RIVER
SCALE
305 m
1000 FT.
LEGEND
○ MONITOR WELL
● LEACHATE WELL
⊙ SURFACE WATER SAMPLING POINT
* SOURCE OF HISTORICAL WATER QUALITY DATA

Figure 4. Location of monitoring points at the hillfill site.

TABLE 3. MONITOR WELL CONSTRUCTION DETAILS - HILLFILL[a]

MP #	Well depth	Total[b] casing	Type casing	Section slotted	Elevation[c] top of casing	Reference[d]	Surface elevation
1	19.0 (62.4)	19.2 (63.0)	3.18 cm (1.25 in.) PVC	19.0–18.7 (62.4–61.4)	220.66 (739.95)	0.18 (0.60)	220.48 (723.35)
2	24.4 (80.0)	26.9 (88.3)	15.24 cm (6.00 in.) Steel	24.4– 7.9 (80.0–26.0)	244.97 (803.70)	2.51 (8.25)	242.45 (795.45)
3	11.9 (39.0)	12.1 (39.6)	3.18 cm (1.25 in.) PVC	11.9–11.6 (39.0–38.0)	220.67 (723.97)	0.19 (0.62)	220.48 (723.35)
4	7.9 (25.9)	8.0 (26.3)	3.18 cm (1.25 in.) PVC	7.9– 7.6 (25.9–24.9)	220.66 (723.95)	0.12 (0.40)	220.54 (723.55)
5	5.2 (17.2)	5.4 (17.6)	3.18 cm (1.25 in.) PVC	5.2– 4.9 (17.2–16.2)	219.44 (719.95)	0.14 (0.45)	219.30 (719.50)
6[e]	10.6 (34.8)	10.8 (35.3)	3.18 cm (1.25 in.) PVC	10.6–10.3 (34.8–33.8)	219.47 (720.04)	0.16 (0.54)	219.30 (719.50)
9	6.1 (20.0)	6.2 (20.4)	3.18 cm (1.25 in.) PVC	6.1– 5.8 (20.0–19.0)	216.56 (710.50)	0.11 (0.35)	216.45 (710.15)

(Continued)

TABLE 3. MONITOR WELL CONSTRUCTION DETAILS - HILLFILL[a]

MP #	Well depth	Total[b] casing	Type casing	Section slotted	Elevation[c] top of casing	Reference[d]	Surface elevation
10	5.7 (18.6)	6.3 (20.6)	5.08 cm (2.00 in.) PVC	5.7- 2.6 (18.6- 8.6)	216.23 (709.40)	0.61 (2.00)	215.62[f] (707.40)
11	45.7 (150.0)	25.0 (82.0)	12.70 cm (5.00 in.) Steel	Open Hole	-----[g]	----	219.46[f] (720.00)
12	4.0 (13.0)	4.9 (16.0)	5.08 cm (2.00 in.) PVC	4.0- 0.9 (13.0- 3.0)	216.10 (709.00)	0.91 (3.00)	215.19[f] (706.00)
13[h]	----	----	-------	-------	-----	----	------
15[h]	----	---	-------	-------	-----	----	------

a Measurements in meters (feet) unless otherwise indicated.
b Total casing is equal to the casing in the ground plus casing above ground (Reference).
c All elevations relative to mean sea level.
d Reference above ground surface from which water level measurements are taken.
e Source of historical water quality data.
f Elevation estimated from USGS topographic map.
g Dashes indicate information not available.
h Existing water supply wells. No completion data available.

till. MP #3 is 11.9 m (39.0 ft) in depth and was completed in clayey gravel. MP #4 was completed in sand and gravel at 7.9 m (25.9 ft). During the study period, each of these three wells exhibited a different water level. MP #5 is located north of the fill. It is 5.2 m (17.2 ft) in depth and was completed in sandy gravel. MP #9 is adjacent to the northwestern edge of the fill and was completed in clay till at a depth of 6.1 m (20.0 ft).

MP #10 and #12 were installed before the first sampling round. They were drilled with augers and completed with 5.08 cm (2.00 in) PVC casing. Each was fitted with a 3.0 m (10.0 ft) section of well screen and gravel packed to prevent any plugging of the slots. MP #10 is located at the western side of the fill. The geologic materials penetrated during its construction include 2.6 m (8.5 ft) of silty, clayey gravel followed by sand containing varying amounts of clay, silt, and gravel. It was completed at 5.7 m (18.6 ft). MP #12 is situated north of the fill near a swampy area. Logs describe 0.8 m (2.5 ft) of soil, 0.8 m (2.5 ft) of loess, dense clay to a depth of 2.6 m (8.5 ft) followed by 0.9 m (3.0 ft) of silty, clayey sand. The well was completed at 4.6 m (15.0 ft) in sandy gravel.

MP #11, #13, and #15 were existing water supply wells. MP #11 is located south of the landfill and is 45.7 m (150.0 ft) in depth. Logs describe 25.0 m (82.0 ft) of unconsolidated sediments overlying dolomite bedrock; the well was cased to bedrock with 12.70-cm (5.00-in) steel casing. MP #13 is located northeast of the hillfill and the large lake, and MP #15 is located east of the hillfill; no logs are available for these wells.

The monitoring points were so located that samples could be obtained showing the quality of upgradient ground-water, ground water adjacent to the landfill at various depths, downgradient ground-water, surface water, and leachate. MP #12 and #13 provided upgradient ground-water samples from two depths. MP #12 is a shallow monitoring well completed in the unconsolidated glacial formations, and MP #13 is a deep production well completed in the bedrock aquifer.

MP #1, #3, #4, #5, and #9 yielded ground-water samples from points adjacent to the toe of the landfill. MP #1, #3, and #4, a nest of wells, were each completed at a different depth in the glacial deposits. MP #5 and #9 provided shallow ground-water samples from other points located around the base of the hillfill.

MP #10, #11, and #15 provided downgradient ground-water samples from two depths. MP #10 is a shallow downgradient monitoring well and MP #11 is a production well completed in the bedrock aquifer. MP #15 is a water supply well also completed in the bedrock aquifer. Downgradient surface water samples were collected from the small man-made groundwater-fed lake at MP #7 and from the large lake at MP #8. MP #2 was completed within the hillfill and monitors leachate quality.

In addition to the data obtained from these monitoring points, historical water quality data was also obtained for MP #6, the shallow well immediately adjacent to MP #5, and for the reservoir, MP #14.

Particle Size Analyses

To aid in the quantification of attenuation characteristics at the hillfill site, particle size analyses were conducted on five samples obtained during the drilling of MP #10 and MP #12 (see Appendix B). Samples were available only from these two wells, as all other wells had been emplaced prior to the study period.

Table 4 shows the results of particle size analyses conducted on three drilling samples from MP #10 and two drilling samples from MP #12. All three samples from MP #10 are glacial outwash which become progressively coarser with depth. The shallower MP #12 sample is loess and has a greater percentage of finer material than has the deeper outwash sample. There was a layer of dense plastic clay penetrated during the drilling of MP #12 (see Appendix A, Well Logs) which was not analyzed because it was essentially all clay. None of the five samples analyzed shows a particularly large amount of clay present for sorption of leachate by matrix material.

Hydrogeology of the Hillfill Site

The hillfill is situated in an area of relatively low relief and poor drainage developed on interbedded glacial sands, silts and clays. The hillfill itself is the major topographic feature. Ground water in the vicinity of the hillfill moves in numerous small, partly interconnected flow systems resulting from the intertonguing glacial tills and outwash. Typically, there are shallow recharge/discharge water table systems which are interconnected by leakage with deeper semiartesian systems which in turn leak into the main bedrock aquifer. Thus any recharge moves through several "stair stepped" flow systems before it becomes part of the main ground-water aquifer.

Since ground water represents a major portion of the drinking water supply for this part of the country, it has been studied and quantified; water budgets have been developed

TABLE 4. PERCENTAGE OF SEPARATES BY WEIGHT FOR THE GEOLOGIC MATERIALS AT THE HILLFILL.[a]

Sample Description	% Clay	% Silt	% Sand	% Coarse Fragments
MP #10 Outwash 2.6-4.6 m (8.5-15.0 ft)	8	9.5	40.5	42
MP #10 Outwash 4.1-6.1 m (13.5-20.0 ft)	2	7	37	54
MP #10 Outwash 7.2-7.6 m (23.5-25.0 ft)	1	5	23	71
MP #12 Loess 1.1-1.5 m (3.5- 5.0 ft)	8	16	67	9
MP #12 Outwash 2.6- 4.6 m (8.5-15.0 ft)	2	10.5	26.5	61

[a] Size limits for the soil separates are based on the U. S. Department of Agriculture system. The diameter range for separates is:

Clay, less than 0.002 mm
Silt, 0.002 - 0.05 mm
Sand, 0.05 - 2.0 mm
Coarse Fragments, greater than 2.0 mm

on a county-by-county basis. The water budget for the County in which the hillfill is located is well developed and is based on a long record of precipitation, stream gaging, and assessment of well yields and water level fluctuations. It can be used to estimate leachate generation by the hillfill. The County water budget will therefore be presented and modifications will be introduced which will allow it to more accurately represent the particular hydrogeologic characteristics of the hillfill site.

The County water budget indicates that, of the 86.48 cm (34.05 in) of average precipitation (PPT) which falls in the area, approximately 65 percent is lost to evapotranspiration (ET), 10 percent runs off as surface water (SW) and 25 percent recharges the ground water (GW). The budget can therefore be expressed as:

$$\begin{array}{ccccccc} \text{PPT} & = & \text{ET} & + & \text{SW} & + & \text{GW} \\ 86.48\ \text{cm} & = & 56.64\ \text{cm} & + & 8.49\ \text{cm} & + & 21.36\ \text{cm} \\ (34.05\ \text{in}) & = & (22.30\ \text{in}) & + & (3.34\ \text{in}) & + & (8.41\ \text{in}) \end{array}$$

This is a carefully-developed water budget which is applicable to the region on a long-term basis. A groundwater (GW) recharge value of 25 percent is used because the region is generally level and poorly drained. Surface runoff, in response to precipitation events, is comparatively slow and water has time to infiltrate into the soil. The hillfill, however, has steeper slopes than is typical for the region because it has been designed to promote runoff and retard infiltration. Therefore, it is appropriate to increase the runoff component (SW) in the water budget to account for this difference. Using standard engineering practices for estimating runoff for an area such as the hillfill having grass slopes, the runoff component (SW) should be altered to represent 15 percent of the total precipitation. This would reduce recharge (GW) into the hillfill to 16.70 cm (6.5 in).

The hillfill was developed on a 16-ha (40-ac) base and was lined with two feet of locally obtained clay prior to filling. Leachate generation by the hillfill can be estimated using the modified water budget and the area of the hillfill base. Multiplying 16.70 cm (6.58 in) of average annual infiltration by the 16-ha (40-ac) hillfill base yields 27,057 m^3 (21.93 ac-ft) per year of potential leachate generation. The leachate leaks through the clay liner and recharges the ground water below the site.

Figure 5 shows a cross section of the hillfill taken along line AA' (shown on Figure 6) and passing from west to east through the stream, MP #9, MP #2, the nest of MP #1, #3, #4 and the large lake. The hillfill was constructed on

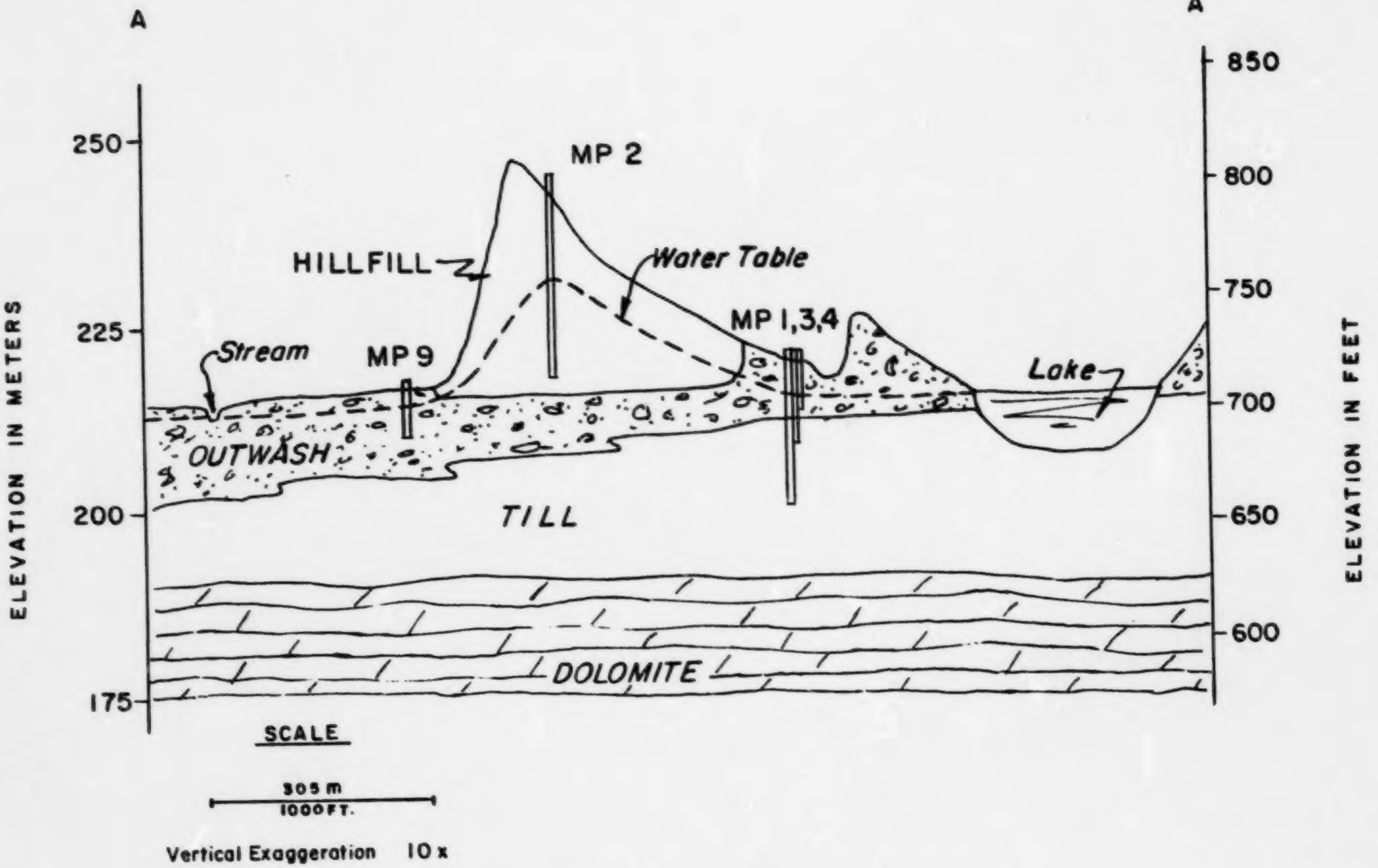

A
A'
250
225
200
175
ELEVATION IN METERS
850
800
750
700
650
600
ELEVATION IN FEET
MP 2
HILLFILL
Water Table
MP 1,3,4
Stream
MP 9
Lake
OUTWASH
TILL
DOLOMITE
SCALE
305 m
1000 FT.
Vertical Exaggeration 10 x

Figure 5. Cross section of the hillfill site.

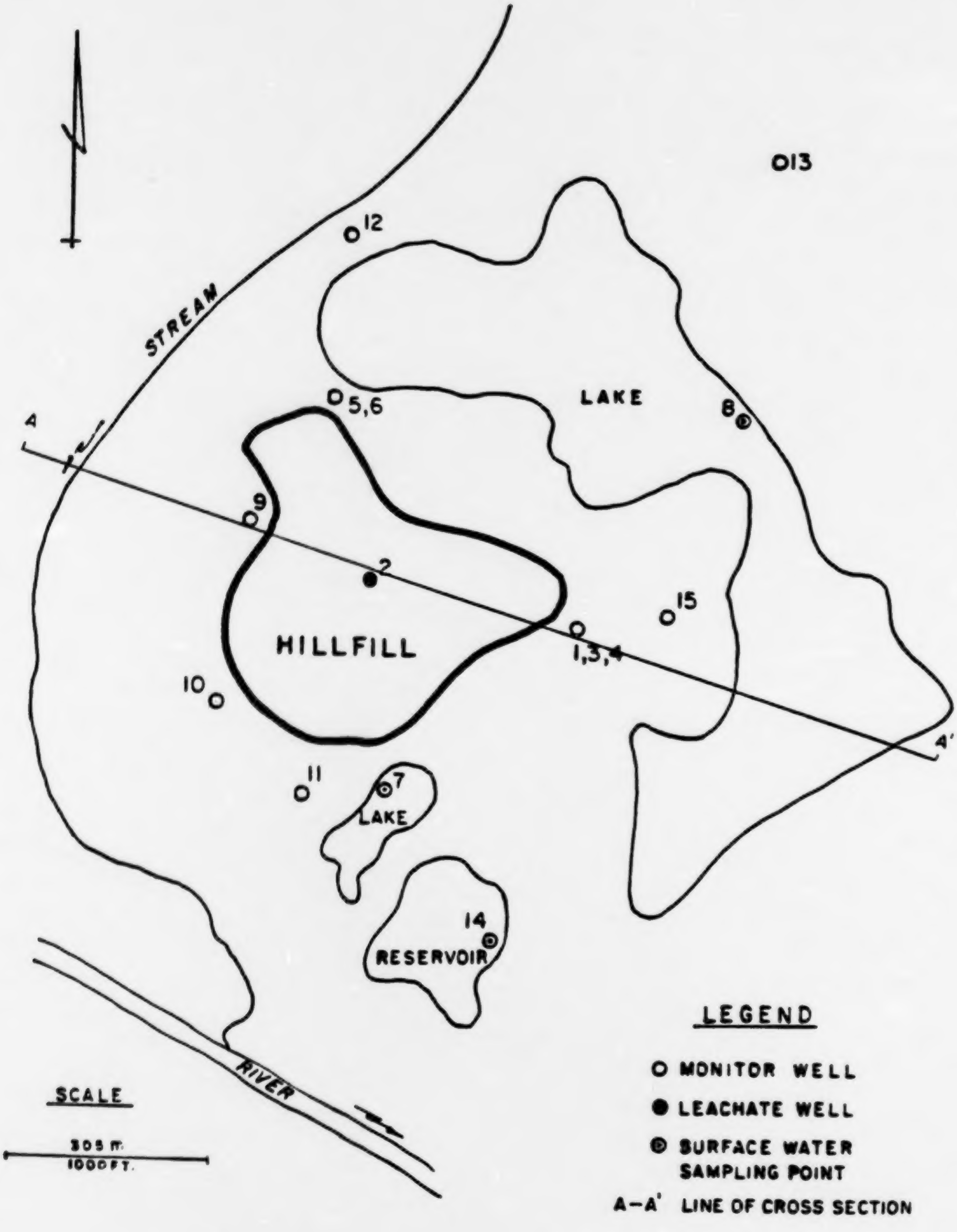

O13
O12
STREAM
O5,6
LAKE
8
A
9
2
HILLFILL
15
1,3,4
10
A'
11
7
LAKE
14
RESERVOIR
RIVER
SCALE
305 m
1000 FT.
LEGEND
○ MONITOR WELL
● LEACHATE WELL
◉ SURFACE WATER SAMPLING POINT
A–A' LINE OF CROSS SECTION

Figure 6. Map showing the location of the line of cross section, AA'.

a thin base of slowly permeable clay which overlies approximately 11 m (35 ft) of glacial outwash. Although the hillfill was originally constructed with a 3.7 m (12.0 ft) separation between the bottom of the fill and the ground-water table, water levels in the wells indicate that a ground-water mound has formed within the hillfill. It is not apparent whether this mounded water is contiguous with the ground-water table or if it is a "saturated refuse mound" that is separated from the actual water table by a thin unsaturated zone.

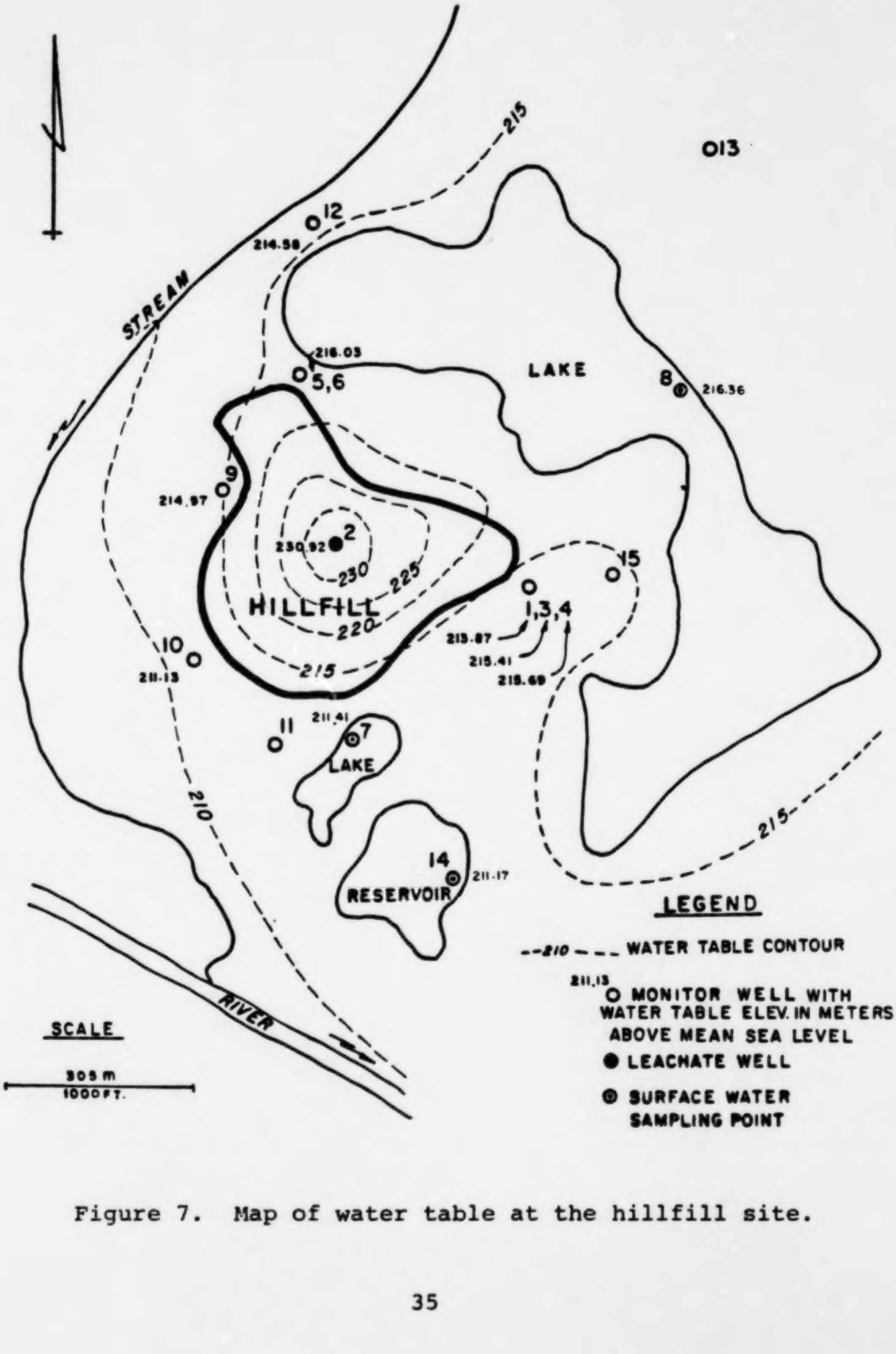
Depth to the water table around the fill ranges from 0.6 to 6.4 m (2.0-21.0 ft, see Appendix C). The average seasonal fluctuation in the water table ranges from 0.6 to 1.2 m (2.0-4.0 ft).

Whether there are two water tables within and directly below the hillfill or not, the leachate that is produced will enter the deeper flow system almost entirely under conditions of saturated flow. Any division between saturated refuse and the "true water table" that may exist will be thin and negligible for the purpose of assessing attenuation mechanisms and the length of flow paths.

The clay base, although potentially a zone for adsorption of leachate, is comparatively thin compared to the large quantity of refuse mounded above it. As noted previously, the average volume of refuse per area is 47,500 m^3/ha (25,000 yd^3/ac). This thin base is relatively ineffective in attenuating the leachate. Therefore, most of the leachate leaving the hillfill will not be significantly altered by the clay in its chemical constitution.

After leaving the hillfill, leachate moves through several stages of the deeper flow system because of the complexity of the intertongued glacial till and outwash. The rate and direction of flow change depending on the thickness of the slowly permeable tills and the more permeable outwash. Leachate is significantly diluted and dispersed along this flow path and ultimately recharges into the dolomite bedrock aquifer at approximately 24 m (80 ft) below the hillfill or discharges laterally to the stream.

The recharge gradients are reflected in the measured water levels in MP #1, #3, and #4. The shallowest depth to water of 4.9 to 6.4 m (16.0-21.0 ft) below grade was found in MP #4, the shallow well. A greater depth to water of 5.2 to 6.4 m (17.0-21.0 ft) was found in MP #3, the intermediate depth well. The greatest depth to water of 6.7 to 7.6 m (22.0-25.0 ft) was found in the deep well, MP #1. The water table at the hillfill radiates outward in all directions and then joins the regional ground-water gradient to the south (see Figure 7).



STREAM
LAKE
LAKE
RESERVOIR
RIVER
HILLFILL
215
230
225
220
215
210
215
O13
O12
214.58
216.03
O5,6
8
216.36
9
214.97
230.92
2
15
1,3,4
213.87
215.41
215.69
10
211.13
11
211.41
7
14
211.17
SCALE
305 m
1000 FT.
LEGEND
--210 --- WATER TABLE CONTOUR
211.13
O MONITOR WELL WITH WATER TABLE ELEV. IN METERS ABOVE MEAN SEA LEVEL
● LEACHATE WELL
⊙ SURFACE WATER SAMPLING POINT

Figure 7. Map of water table at the hillfill site.

Water Chemistry at the Hillfill Site

The hillfill is underlain by at least 18 m (60 ft) of unconsolidated glacial deposits consisting primarily of outwash and a low permeability clay till. The dolomite bedrock beneath the glacial deposits is a heavily-used aquifer. Ground water is mounded within the hillfill and moves outward in all directions with the steepest gradient to the west and southwest.

Bar graphs were constructed using the mean concentrations of alkalinity and acidity, total dissolved solids (TDS) and total Kjeldahl nitrogen (TKN), chemical oxygen demand (COD) and total organic carbon (TOC), see Figures 8, 9, and 10 and Section 2. The mean concentrations of these parameters were calculated for all monitoring points for the study period of May 17, 1978 through July 24, 1979 (see Appendix E); however, alkalinity, acidity, and TDS were not analyzed during the May 17, 1978 round.

Several factors affected the analyses. The May 1978 samples were not filtered and thus contained greater amounts of sediment and organic material; analyses from this sampling round were elevated compared to those of the four subsequent rounds. MP #10 and #12 were sampled in November 1978 the day after they had been drilled; they had not yet reached chemical equilibrium and this accounts for their elevated values during the November 1978 round. MP #12, the shallow background well, is located next to a swampy discharge area and a stream that is reportedly contaminated with sewage. MP #5 is located adjacent to an outhouse facility which is used heavily during the summer and fall months. The values for this monitoring point for the November 1978 and July 1979 sampling rounds are generally much higher than they are for the January and April 1979 rounds; the other wells do not show similar increases in concentrations during those two months (see Appendix E). Therefore, it is possible that there is contamination from sewage in this area in the vicinity of MP #5.

Alkalinity and acidity are shown on Figure 8. The bar graphs of these two parameters exhibit relationships among monitoring points that are similar to each other. Background ground-water quality is represented by MP #13. Alkalinity is 355 mg/l and acidity averaged -312 mg/l. These values are very similar to data about the regional ground-water quality in the bedrock aquifer. MP #12 represents shallow background ground-water quality in the glacial aquifer and has alkalinity of 471 mg/l and acidity of -473 mg/l, values consistent with those in the area. The leachate (MP #2) was very alkaline, showing 3,178 mg/l alkalinity and -2,528 mg/l acidity.

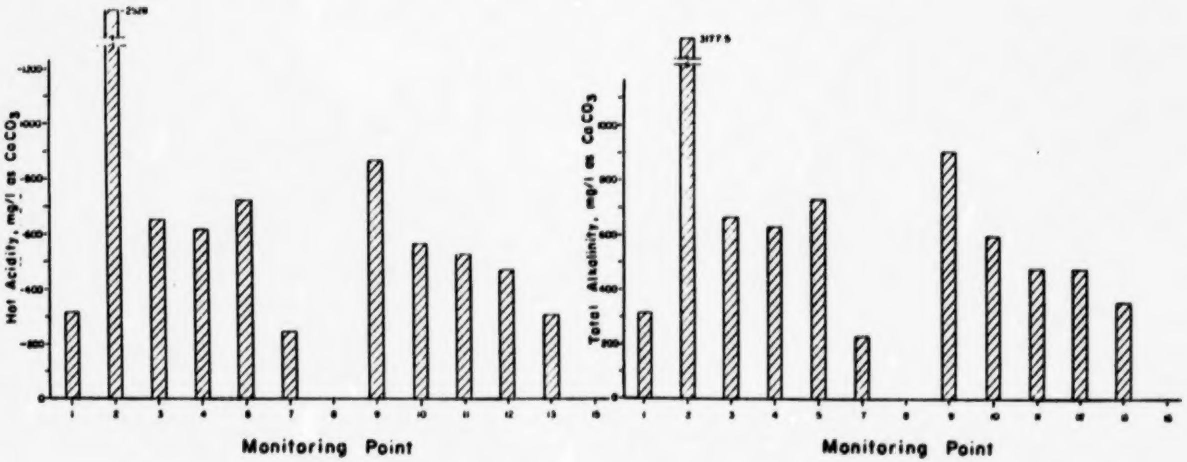


Figure 8. Bar graphs for alkalinity and acidity at the hillfill site.

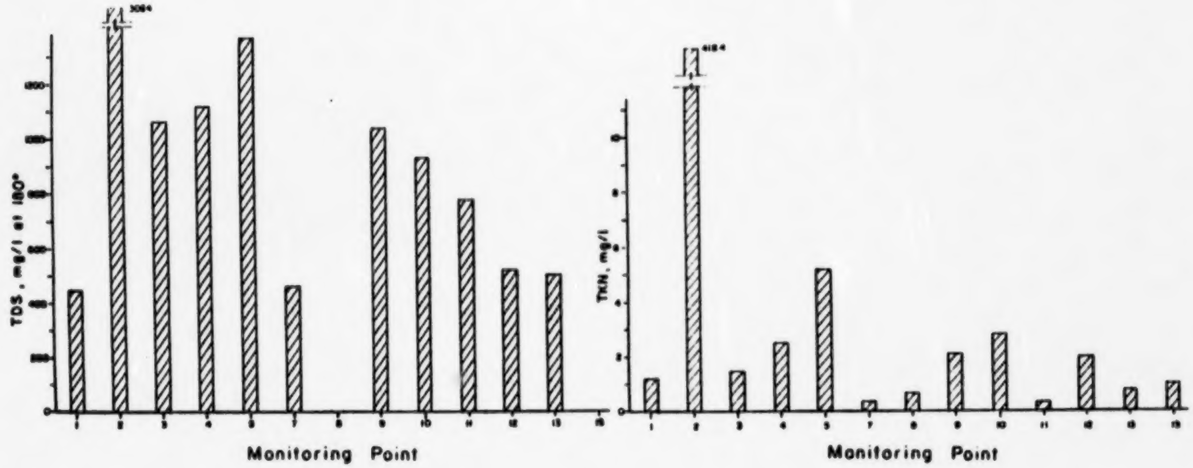


Figure 9. Bar graphs for TDS and TKN at the hillfill site.

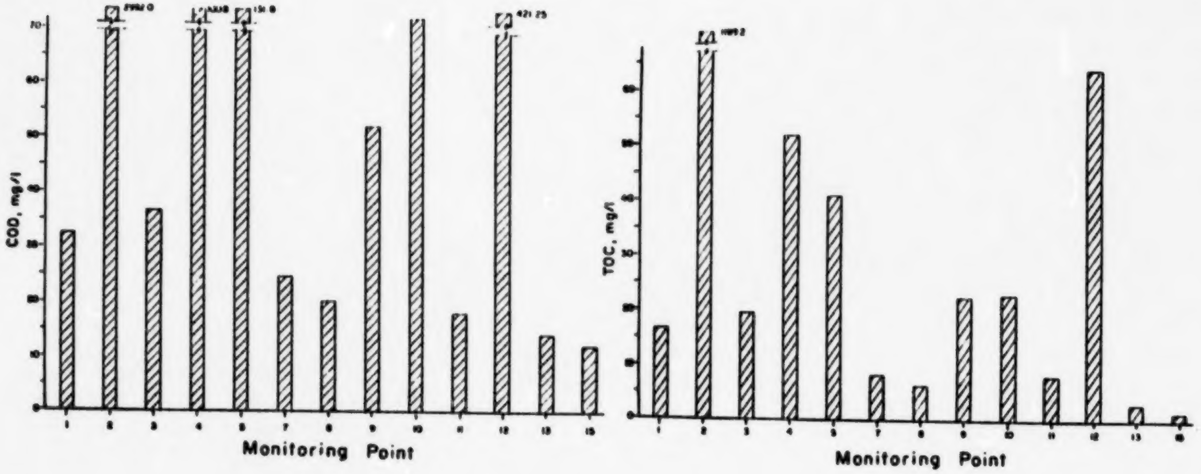


Figure 10. Bar graph for COD and TOC at the hillfill site.

The shallow downgradient wells (MP #3, #4, #5, #9, and #10) have mean alkalinity concentrations elevated above those in the background wells (MP #12 and #13) indicating that leachate has reached them. Average concentrations for alkalinity, in decreasing order, were MP #9 (899 mg/l), MP #5 (729 mg/l), MP #3 (660 mg/l), MP #4 (629 mg/l), and MP #10 (589 mg/l). Values for acidity in these wells followed the same pattern; MP #9 (-866 mg/l), MP #5 (-722 mg/l), MP #3 (-646 mg/l), MP #4 (-615 mg/l), and MP #10 (-562 mg/l).

The deep downgradient well (MP #11) is located in the direction of dominant ground-water flow and has slightly higher concentrations (alkalinity of 472 mg/l) than does MP #13 (background). Acidity exhibited a mean value of -527 mg/l. MP #1, the deep downgradient member of the well nest, has lower alkalinity (317 mg/l) than does MP #13 indicating that contamination has not moved into the deep aquifer at this location or that it has been attenuated by clayey till. The surface water (MP #7) had the lowest alkalinity of all the monitoring points (225 mg/l); acidity was -241 mg/l. This indicates that the surface water at this point has not been affected by leachate.

Figure 9 shows the bar graphs of the average concentrations of TDS and TKN in each of the monitoring points. The bar graph for TDS shows similar relationships among monitoring points to those seen in the bar graphs for alkalinity and acidity. TDS in MP #13 was 492 mg/l, consistent with regional background values; at MP #12 TDS averaged 513 mg/l, also consistent with values in the area from the shallow aquifer. TDS in the leachate averaged 3,084 mg/l, nearly one order of magnitude greater than background values.

The shallow downgradient wells, MP #3, #4, #5, #9, and #10, again showed the effects of leachate. The water in the wells showed elevated concentrations at a level about twice the maximum contaminant level (MCL) for TDS, 500 mg/l, and, in order of decreasing concentrations, MP #5 (1,360 mg/l), MP #4 (1,108 mg/l), MP #3 (1,063 mg/l), MP #9 (1,036 mg/l), and MP #10 (922 mg/l).

The deep downgradient well (MP #11) had a TDS concentration (769 mg/l) slightly higher than that at MP #13; this indicates that minimal contamination may be reaching the ground water here. Again, MP #1 (445 mg/l) and #7 (453 mg/l) had levels of TDS lower than those of the background wells.

The bar graph for TKN, also shown on Figure 9, shows that TKN concentrations in the leachate, MP #2, are very high (418.4 mg/l). Background levels of TKN in the bedrock aquifer (MP #13, 0.74 mg/l) are less than 1.0 mg/l; MP #15 and #11 also exhibit low TKN values (0.94 and 0.30 mg/l, respectively). The shallow background well, MP #12, shows a higher mean TKN concentration of 1.98 mg/l; this may be attributed to reducing conditions in the adjacent swampy area.

The shallow downgradient wells, MP #4, #5, #9, and #10, have higher TKN values than those in either the deep or shallow background well. The elevated values in these wells show contamination from leachate. In order of decreasing concentrations, they are MP #5 (5.14 mg/l), MP #10 (2.80 mg/l), MP #4 (2.48 mg/l), and MP #9 (2.04 mg/l). MP #5 shows an unusually high TKN concentration during July 1979 (see Appendix E) which may be attributed to sewage contamination.

TKN concentrations in MP #1 (1.18 mg/l) and MP #3 (1.46 mg/l) are nearly two times higher than those in MP #13, the deep background well. These values are lower than that in the shallow background well, MP #12, but indicate possible slight contamination from leachate. TKN in the surface water monitoring points (MP #7, 0.36 mg/l and MP #8, 0.66 mg/l) is lower than background.

The histograms of COD and TOC are shown on Figure 10. MP #13, the deep background well, had a low mean level of COD (13.93 mg/l). The shallow background well, MP #12, had an elevated mean COD (421.25 mg/l); the November 1978 sampling round was particularly high as the well had been installed one day prior to sampling. During drilling, an organic clay was penetrated. This clay, in addition to the disturbance of chemical equilibrium caused by drilling, increased the organic content of the water and thus, COD (see Appendix E). The leachate had an elevated value for COD of 2,992.0 mg/l.

The shallow downgradient wells (MP #4, #5, #9, and #10) generally had mean concentrations about two orders of magnitude lower than those of the leachate but were elevated above the deep background levels; in order of decreasing concentrations, they were MP #5 (131.80 mg/l), MP #4 (100.80 mg/l), MP #10 (72.00 mg/l), and MP #9 (52.00 mg/l).

MP #1 and MP #3 had COD values similar to each other, 32.20 and 36.40 mg/l, respectively; these values are slightly elevated above that of the deep background well but are considerably lower than those in the shallow downgradient wells. It is interesting to note that at MP #3, alkalinity, acidity and TDS values are similar to those of the other shallow downgradient wells (MP #4, #5, #9, and #10) but that COD is considerably lower than the values for the other shallow downgradient wells.

The deep downgradient wells, MP #11 (COD of 18.00 mg/l) and MP #15 (COD of 12.00 mg/l) exhibited COD concentrations similar to that at MP #13. COD in the surface water, MP #7, (24.25 mg/l) and MP #8 (20.00 mg/l) was relatively low. These values indicate that the leachate generally has not affected the bedrock aquifer and the surface water.

The bar graph for TOC is shown on Figure 10. The relationships among monitoring points shown on this graph are similar to those exhibited on the bar graph for COD. Again, the leachate has high concentrations of TOC (1,189.2 mg/l). The deep background well, MP #13, has a low mean value for TOC of 3.0 mg/l; the shallow background well has a high mean value of 64.8 mg/l.

The shallow downgradient wells exhibit elevated levels of TOC as follows: MP #4 (52.0 mg/l), MP #5 (41.0 mg/l), MP #10 (22.5 mg/l), and MP #9 (22.4 mg/l). As seen with COD, MP #1 and #3 have somewhat lower TOC concentrations of 16.2 and 19.0 mg/l, respectively. These values, however, are slightly elevated above those for MP #13. TOC concentrations at the deep downgradient wells are low; MP #11 had a TOC of 7.9 mg/l and MP #15 had a TOC of 1.4 mg/l. The surface water also showed low TOC values of 8.1 mg/l at MP #7 and 6.3 mg/l at MP #8. This bar graph also demonstrates that there has been essentially no impact on the bedrock aquifer and the surface water.

In summary, the bar graphs indicate that contamination from the hillfill is localized. The leachate in the hillfill is of considerable strength and has affected the shallow ground water in the wells immediately surrounding the hillfill. Minimal effect is seen in the deep monitor wells and leachate has had essentially no effect on the surface water.

To further illustrate the effect of the landfill on ground and surface waters and to illustrate water quality variations among monitoring points, Stiff diagrams were constructed using the average concentrations of sodium, iron, manganese, zinc, chloride, sulfate, nitrate, and phosphate (see Figure 11). The means were calculated using data from the current study period only (May 1978 through July 1979). The November 1978 values for MP #1 were excluded from the preparation of its Stiff diagram because it was atypical, containing a large proportion of sediment.

Background ground water (the bedrock aquifer) is characterized by MP #13. It contains a considerable amount of sodium, little iron, no manganese, and some zinc. Shallow ground water (the glacial aquifer) is characterized by MP #12. Its diagram is similar to that for MP #13 but shows slightly more iron, manganese, chloride, nitrate, and phosphate; concentrations are typical of those in the area.

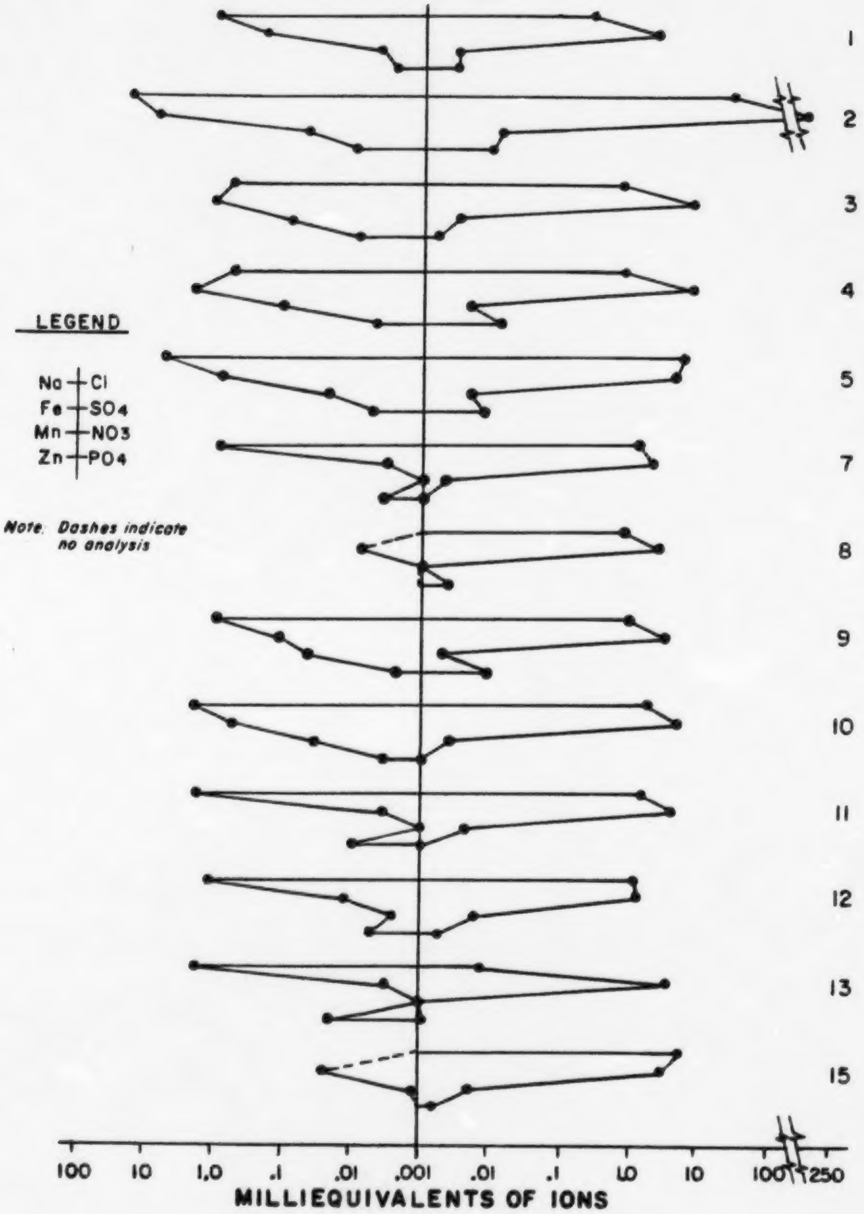


Figure 11. Modified Stiff diagrams showing averaged results of chemical analyses at the hillfill site.

The leachate diagram (MP #2) indicates high concentrations of sodium, iron, manganese, and chloride, very high concentrations of sulfate, and minor amounts of nitrate and phosphate. The shallow downgradient wells, MP #4, #5, #9, and #10, appear to have been impacted to similar degrees, and have diagrammatic shapes similar to that for the leachate. The diagram for MP #5 shows slightly higher sodium and chloride concentrations but increased concentrations of these anions may result partially from sewage contamination (see Appendix E).

The diagrams for the nest of wells (MP #4, #3, and #1) show that ground-water quality improves with depth. MP #1, the deepest well, generally has low levels of cations and anions similar to those of MP #13. Depth-to-water increases from MP #4 to MP #3 to MP #1 which indicates a downward gradient of ground-water flow. The movement of water is from the shallow aquifer toward the deep bedrock aquifer.

The deep downgradient well, MP #11, has a diagrammatic shape very similar to that of MP #13 which indicates that MP #11 has generally not been affected by the landfill. MP #15 is also a deep downgradient well but was sampled only in May of 1978; the diagram is based on the results of this single analysis which was unfiltered. MP #15 does not appear to be affected by leachate. Manganese, chloride, and nitrate values, as shown on this diagram, are slightly higher than concentrations for those parameters in MP #13. Diagrams for the surface water monitoring points (MP #7 and #8) are similar to that of the background well and demonstrate that surface water has not been affected by the landfill.

In summary, the Stiff diagrams, a graphical display of the similarities and differences in cation and anion levels between monitoring points, lead to the same conclusion as that indicated by the bar graphs. The leachate is strong and has reached a localized area surrounding the hillfill.

A nitrogen index was used to delineate redox (oxidation and reduction) zones in the ground water and to determine the location of reducing fronts as leachate migrates from the hillfill (see Figure 12 and Section 2). The ratios were calculated using mean values of TKN and nitrite and nitrate nitrogen (NO_3) for the study period.

The ratio for the leachate (MP #2, 511.5) is high. It contains large quantities of organic nitrogen and ammonia (TKN) but does not contain much nitrite and nitrate nitrogen; reducing conditions exist within the hillfill. Ratios for the ground water in the shallow wells surrounding the hillfill are considerably lower (ranging from 7.60 at MP #3 to 17.83 at MP #10) indicating that the leachate has been partially

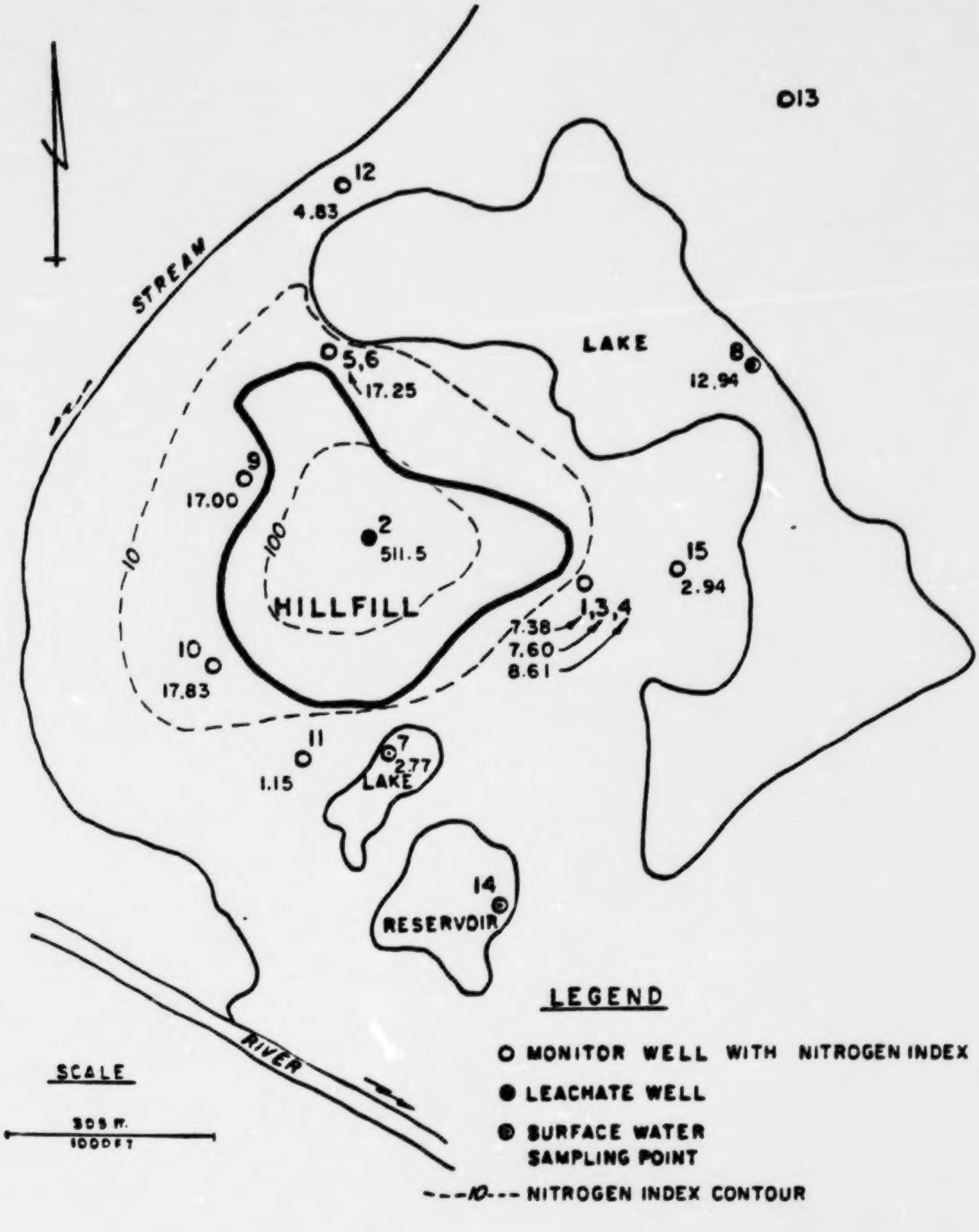

O13
O12
4.83
STREAM
LAKE
8
12.94
O5,6
17.25
9
17.00
2
511.5
100
10
HILLFILL
15
2.94
1,3,4
7.38
7.60
8.61
10
17.83
11
1.15
7
2.77
LAKE
14
RESERVOIR
RIVER
LEGEND
○ MONITOR WELL WITH NITROGEN INDEX
● LEACHATE WELL
⊙ SURFACE WATER SAMPLING POINT
---10--- NITROGEN INDEX CONTOUR
SCALE
305 M.
1000 FT

Figure 12. Nitrogen index showing the ratio of organic nitrogen plus ammonia nitrogen (TKN) to nitrite plus nitrate nitrogen ($NO_2 + NO_3$).

oxidized and attenuated by the time it reaches these wells. The leachate appears to radiate outward from the hillfill in all directions but more leachate migrates to the west and southwest toward MP #9 (17.00) and MP #10 (17.83). MP #5 (17.25) and MP #12 (4.83) both have other potential sources of organic contamination; MP #5 is adjacent to an outhouse and MP #12 is situated adjacent to a swamp where reducing conditions prevail.

The area immediately surrounding the hillfill is transitional between the reduction zone within the hillfill itself and the oxygenated ground-water zone farther from the hillfill. Nitrite and nitrate nitrogen present in the hillfill and in the adjacent wells that are strongly affected by leachate probably originates from infiltrating rainwater or from upgradient recharge water; nitrate present in a reducing environment is either converted to ammonia or denitrified to N_2 or N_2O.

Nitrogen ratios become progressively lower with increasing depth and distance from the hillfill. The well nest at MP #4 clearly shows increasing oxidizing conditions with depth, and MP #1 (approximately 19 m, 62 ft in depth) has the least amount of ammonia and organic nitrogen (the lowest ratio, 7.38) among the three wells; MP #3 has a ratio of 7.60 and MP #4 has a ratio of 8.61.

MP #11, approximately 46 m (150 ft) deep, has the lowest ratio (1.15) of all the wells surrounding the hillfill, indicating that leachate (a reducing front) has not reached the bedrock aquifer adjacent to the hillfill. Although MP #8 exhibits a ratio of 12.94, TKN and nitrate nitrogen are both low, comparable to those values for MP #13. The surface water at MP #7, one of the small ground-water lakes, also has a low ratio (2.77) of reduced to oxidized nitrogen; this indicates that oxidizing conditions prevail in the surface water a short horizontal distance from the hillfill.

The nitrogen indices show that the reduced nitrogen species, organic nitrogen and ammonia, in the leachate migrating from the hillfill are rapidly oxidized as leachate moves both laterally and vertically through the subsurface (glacial outwash and till); primarily oxidizing conditions are present in the bedrock aquifer and in the surface water a short distance (70 m, 230 ft) from the hillfill.

Nitrogen indices were not calculated for MP #6 and #14 because of insufficient data. A ratio could not be calculated for MP #13 because nitrite and nitrate nitrogen (NO_3) was consistently below the detection limit and both reduced nitrogen and oxidized nitrogen must coexist in order to use the ratio.

Pertinent historical data for the hillfill site is limited. Results of analyses are shown in Appendix D for samples of the leachate (MP #2) from February 1969, the downgradient wells (MP #3, #4, #6, and #9) from August 26, 1974 and surface water (MP #7, #8, and #14) from several dates between March 17, 1969 and June 13, 1972. The samples were reportedly unfiltered.

Review of the historical data for MP #2 and comparison of it with the data from the present study period, particularly the May 17, 1978 round as it was unfiltered, shows marked decreases in parameter concentrations since 1969, especially in chloride, COD, TDS, iron, sodium, lead, and zinc. Other parameters that were elevated during the February 1969 round were BOD, hardness, hexane solubles, aluminum, arsenic, boron, barium, potassium, magnesium, and selenium.

In 1974, MP #3 showed little or no effect from the hillfill but since then, concentrations of parameters have increased. MP #4 had elevated concentrations in 1974 and showed similar or slightly higher concentrations in 1978-79. MP #6, adjacent to MP #5, had elevated concentrations in 1974 and had concentrations similar to those in MP #5 for the 1978-79 study period. During 1974, MP #9 was impacted by the hillfill; water quality during the study period (1978-79) is similar or has improved slightly.

The analyses for the surface water monitoring points (MP #7, #8, and #14) from March 1969 through June 1972 generally show no effect from the hillfill; concentrations of those parameters analyzed are most often below the MCLs. Analyses from that period are very similar to those of the present study period (1978 to 1979).

Overall trends observable in both the historical and present data indicate that the leachate has decreased in strength; concentrations of the parameters analyzed have decreased since 1969 and continued to decrease during the 1978-79 study period. Based on these limited analyses, there do not seem to be significant changes in the shallow wells surrounding the hillfill. MP #1 appears to have increasing concentrations, particularly of alkalinity, sulfates, specific conductance, TOC, COD, and solids.

The hillfill lies within a region that contains two hydrogeologic units, the glacial drift aquifer and the Silurian dolomite (bedrock) aquifer. Concentrations of chemical parameters in the glacial drift aquifer are somewhat higher than those in the bedrock aquifer; the bedrock aquifer is the most heavily developed source of ground water in the area.

The hillfill has been generating a leachate of considerable strength since at least 1969 but has decreased in strength. During the study period (1978-79), concentrations have continued to decline.

The impact of the hillfill on ground water is relatively localized; leachate has contaminated the shallow wells in the glacial aquifer immediately surrounding the hillfill. There is evidence, observable in the well nest in the glacial aquifer, that minimal contamination may be moving downward. This may be expected, as there is a downward gradient of ground water demonstrated by water levels in the wells at this location. Leachate radiates outward in all directions from the hillfill, but there seems to be more movement to the west and southwest. As leachate moves through the glacial outwash and clayey till, it can be diluted, attenuated and biologically degraded. It appears that leachate has not contaminated the bedrock aquifer or the surface waters surrounding the hillfill.

Based on historical chemical analyses, the 1978-79 chemical analyses, and field observations, the hillfill is in the final stage of degradation and anaerobic conditions exist within it. This observation is supported by the production of methane gas by the hillfill, the relatively neutral pH of the leachate, and the fact that the analyzed chemical parameters have passed peak concentrations and are now declining.

BALEFILL

The baling of solid waste has been proposed as a solution to many of the perennial problems associated with landfills such as limits on landfill space and duration of use, the number of trucks needed to transfer waste, and the structural stability of landfill sites. This method of waste management also facilitates resource recovery operations. Baling is accomplished by compressing solid waste in a mechanical baler to reduce volume and obtain a dense bale suitable for transportation and landfilling. It has been used in the scrap and salvage industries; its application to general solid waste disposal is relatively recent.

Topographic Position

The balefill lies within the Central Lowlands physiographic province. The preglacial topography was covered by a mantle of glacial deposits which give the topography its present form. Numerous moraine deposits and undrained depressions form hilly, rolling surface features.

Local drainage in the area is poorly integrated. Surface runoff is collected in closed basins, forming a number of small lakes and swamps. The balefill is located in one of these low-lying basins adjacent to another landfill at its southern boundary (see Figure 13). A major southerly flowing river is located 1.6 km (1 mile) to the east of the facility. There are no significant tributaries to this river located near the landfill.

Vegetation consists of woodland and shrubs in the areas with higher elevation and swamp and marsh grasses in the wet areas of the basins. Much of the land surrounding the balefill is devoted to crops and grazing. The balefill is divided into two sections, one of which has been revegetated with grasses. The other section continues in use for the disposal of demolition wastes.

Climate

The climate at the balefill is continental. Polar air affects it throughout the year with the occasional presence of arctic air during the winter. Periods of prolonged heat sometimes occur during the summer as a result of air movement from the south and southwest.

On the basis of data compiled by the U.S. Weather Bureau at a nearby weather station for a 30-year period of record, the mean annual precipitation for the balefill area is 65.88 cm (25.94 in). Precipitation varies throughout the year from a normal low of 1.85 cm (0.73 in) in January to a normal high of 10.01 cm (3.94 in) in June (see Figure 14 and Table 5). April through September are the wettest months accounting for approximately 60 percent of the annual precipitation.

Precipitation for the one-year study period was 9.74 cm (3.84 in) above normal. The months of September 1978, October 1978, December 1978, April 1979, and July 1979 had below normal precipitation; all other months were above normal.

The mean annual temperature for the balefill area is 6.8 C (44.2 F) with a normal low of -11.0 C (12.2 F) occurring in January and a normal high of 22.2 C (71.9 F) in July.

Geology and Soils

The balefill is underlain by Paleozoic bedrock covered by a mantle of Quaternary unconsolidated glacial and alluvial deposits. The bedrock of the area is part of a regional basin, a broad, relatively shallow structure of Ordovician-

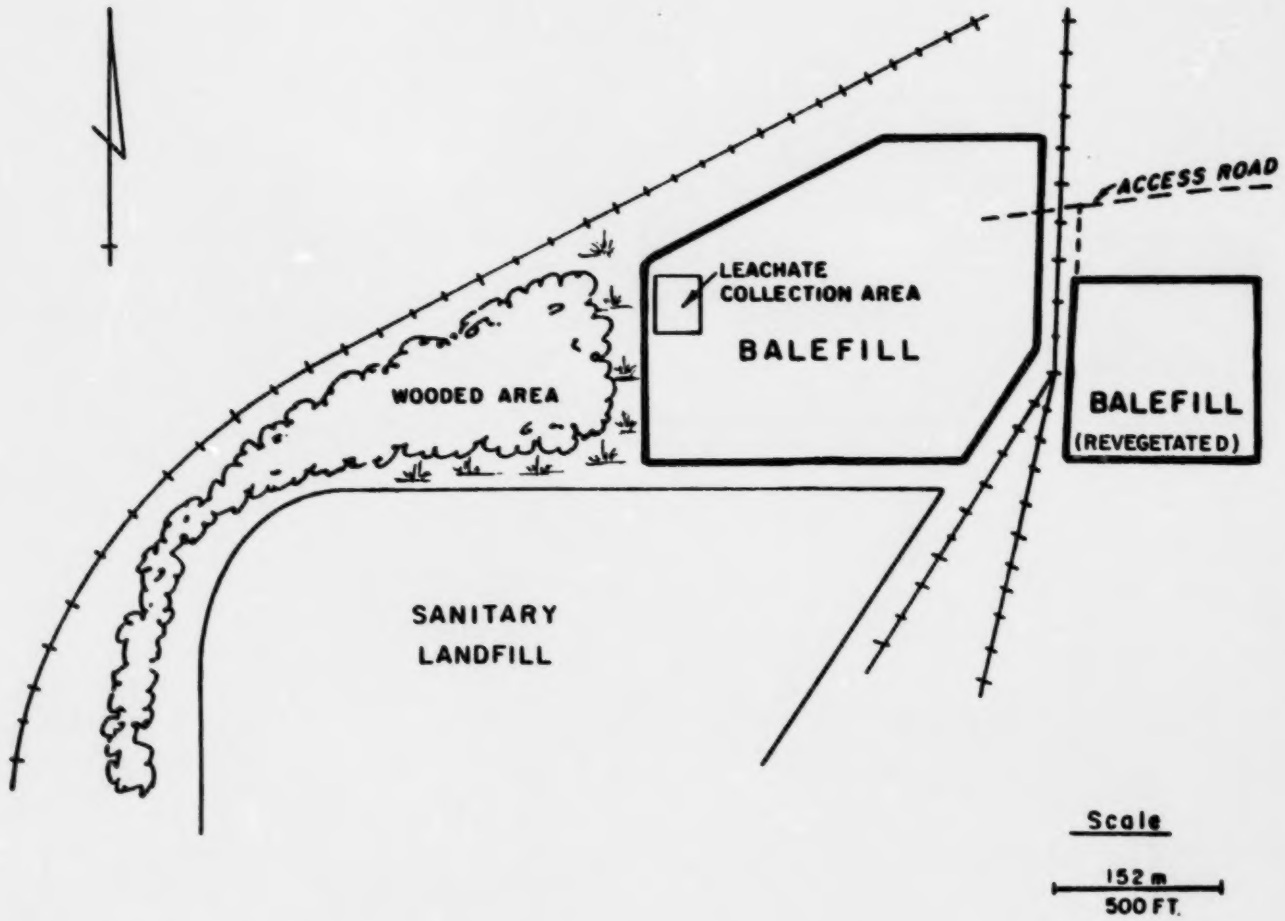

ACCESS ROAD
LEACHATE COLLECTION AREA
BALEFILL
BALEFILL (REVEGETATED)
WOODED AREA
SANITARY LANDFILL
Scale
152 m
500 FT.

Figure 13. Map of the balefill site.

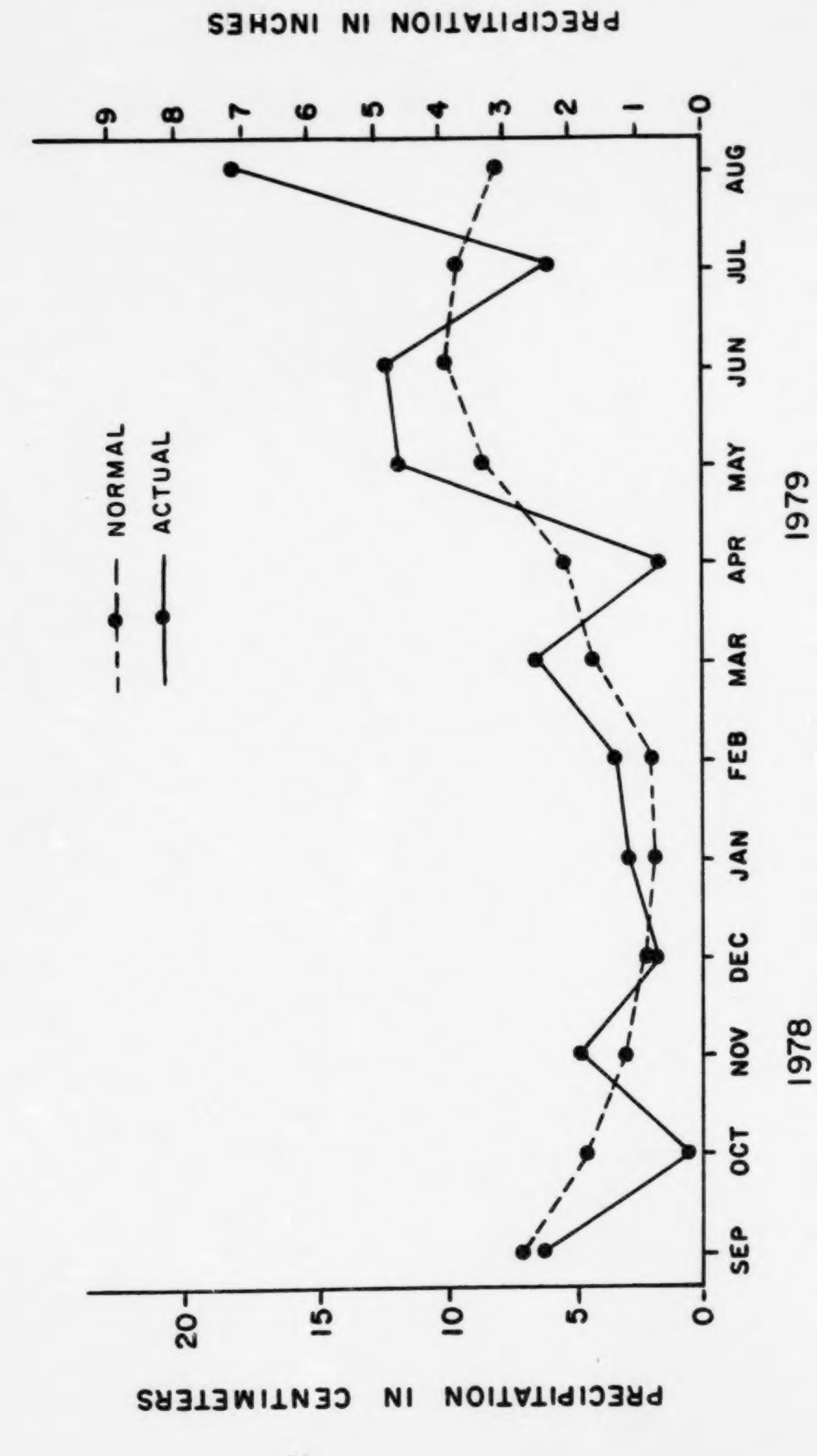


Figure 14. Graph of precipitation for the balefill.

TABLE 5. MONTHLY PRECIPITATION DATA[a] - BALEFILL

Date	Normal	Actual	Departure from normal
9/78	6.93 (2.73)	6.27 (2.47)	- 0.66 (-0.26)
10/78	4.52 (1.78)	0.48 (0.19)	- 4.04 (-1.59)
11/78	3.05 (1.20)	4.67 (1.84)	1.63 (0.64)
12/78	2.26 (0.89)	2.24 (0.88)	- 0.03 (-0.01)
1/79	1.85 (0.73)	2.77 (1.09)	0.91 (0.36)
2/79	2.13 (0.84)	3.53 (1.39)	1.40 (0.55)
3/79	4.27 (1.68)	6.48 (2.55)	2.21 (0.87)
4/79	5.18 (2.04)	1.68 (0.66)	- 3.51 (-1.38)
5/79	8.56 (3.37)	11.56 (4.55)	3.00 (1.18)
6/79	10.01 (3.94)	12.14 (4.78)	2.13 (0.84)
7/79	9.37 (3.69)	5.94 (2.34)	- 3.43 (-1.35)
8/79	7.75 (3.05)	17.88 (7.04)	10.13 (3.99)
TOTAL	65.88 (25.94)	75.64 (29.78)	9.74 (3.84)

[a] Measurements in cm (in)

and Cambrian-age rocks which dip gently toward the center of the basin located northeast of the landfill. Beneath the balefill, these strata have been dissected by a vast east-west trending bedrock valley which resulted from deep erosion of the original bedrock surface. The buried valley extends more than 2400 m (8000 ft) in width and greater than 60 m (200 ft) in depth; it cuts through the Ordovician-age Prairie du Chien Group (dolomites interbedded with sandstone, siltstone and shale) through the Cambrian-age Jordan Sandstone (a valuable aquifer) and into the Cambrian-age St. Lawrence (an aquitard) and Franconia Formations (not typically used as a water sypply). The bedrock beneath the balefill, overlain by a considerable thickness of unconsolidated sediments, consists of the St. Lawrence Formation of silty, sandy dolomites and the Jordan Sandstone.

The bedrock is overlain by approximately 137 m (450 ft) of unconsolidated Pleistocene sediments (see Figure 15). Immediately overlying the bedrock are moderately to well-sorted alluvial sands and gravels with minor amounts of silt, possibly of preglacial origin; the thickness of these sediments is on the order of 100 m (328 ft). The sands and gravels grade upward into stratified drift composed of clay, sand and gravel with thicknesses ranging from 9 to 37 m (30-120 ft).

A thin till with thicknesses up to 15 m (50 ft) was deposited over the stratified sediments. The dense reddish-brown till consists predominantly of silty and gravelly sands of moderately uniform texture derived from the reworking of the underlying material by a subsequent ice advance. There are also some large angular fragments of limestone and some thin lenses of water-bearing sand within the till.

Discontinuous deposits of outwash and scattered glacial lacustrine sediments occur at the surface throughout the area. These sediments resulted from the ablation of the ice which had deposited the underlying till. Lacustrine sediments were deposited in kettle lakes. They consist of grey to dark brown and black poorly-sorted silts. The outwash consists of moderate to poorly sorted sand and finer sediments; the better sorted layers are generally more permeable. The outwash is thickest under the western portion of the site and is absent under the eastern portion of the site.

A till formed by another minor ice advance is present in hills surrounding the balefill site. This till, consisting of very poorly-sorted material, primarily sand and silt, is of low permeability. The unconsolidated glacial materials are not considered to be valuable sources of ground water. Areas mapped as Made Land in Figure 15 were either excavated

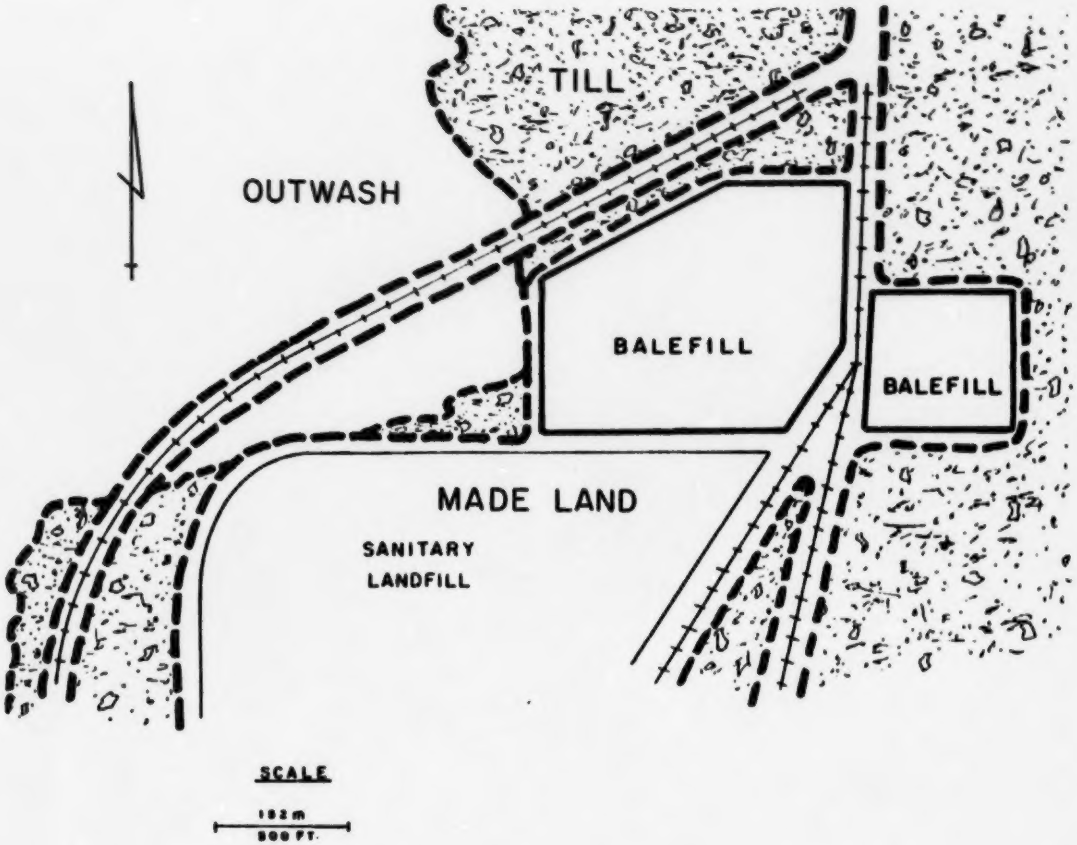

TILL
OUTWASH
BALEFILL
BALEFILL
MADE LAND
SANITARY
LANDFILL
SCALE
152 m
500 FT.

Figure 15. Map of surficial geology at the balefill site.

or filled during landfilling operations. The railroad beds also required grading and therefore are mapped as Made Land.

The soils of the surrounding area and soils originally underlying the balefill were mapped by the USDA Soil Conservation Service. The Waukegan silt loam soil series is developed in glacial outwash. The Burnsville, Hayden, Kingsley and Scandia loam and sandy loams have a parent material of glacial till. These soils are deep, well-drained and moderately permeable.

The original soils at the balefill site were disturbed during initial site preparation; they and underlying till were stripped from nearby hills and used for leveling the site prior to landfilling. The soil layer beneath the balefill is thin in comparison to the great thickness of unconsolidated glacial and alluvial deposits.

Landfill Operations

The balefill was privately operated from January 1971 until the end of June 1974 when operations were discontinued. The site is now being used for the disposal of relatively inert demolition wastes. While the facility had been operating as a balefill, it served a population of 300,000 and received mixed municipal wastes including residential, industrial, and commercial wastes. No hazardous substances were accepted.

The landfill is situated on a 16-ha (39-ac) site. Prior to the filling operation, the site consisted of two surface depressions of approximately 4 ha (9 ac) and 12 ha (30 ac) in size. The depressions were separated by a railroad right of way. They received surface runoff from the surrounding higher topography and were swampy because drainage from them was poor.

The site had been prepared for filling by the removal of trees from the depressions which were then leveled. Till was removed from the surrounding hills and placed in the leveled areas to provide a working base for the filling operation. A drainageway was provided from the smaller to the larger depression and surface features were altered to provide general drainage away from the balefill to the west and northwest. Upon completion, surface runoff from the site was diverted away from the landfill to the west and north.

Solid waste received at the plant was processed at an average of 14 hr/day, 5 day/wk, 49 wk/yr. Metal and corrugated cardboard were removed and the remaining refuse was compacted into unbound bales by a hydraulic press at a rate of 28,200 kg/hr (62,170 lb/hr). Each bale measured approximately 1.1 m (3.6 ft) high, 1.1 m (3.6 ft) wide, and 1.4 m (4.6 ft) long. They weighed 1,320 kg (2,900 lb) each with an average density of 800 kg/m^3 (1,350 lb/yd^3) which is nearly 10 times greater than the precompacted refuse density. Approximately 300 bales/day were produced and transported to the landfill via transfer trailer where they were unloaded by a forklift.

Landfilling began at the smaller depression in January 1971. The first row of bales was placed against an embankment at the edge of the depression and succeeding rows were placed adjacent to them. Bales were typically stacked in rows from 80 to 120 bales long and tiers three bales high. The stacking was staggered to provide stability to the rows and to minimize exposed vertical void spaces. Cover material consisting of native tills was used to cover the completed rows to an average depth of 15 cm (6 in) once or twice weekly. When the first layer of bales had been completed, an additional 15 cm (6 in) layer of cover material was applied. Succeeding layers of bales and cover material were added until the desired final height was obtained. The smaller depression was completely filled in this manner and a final surface cover of 0.6 m (2 ft) was applied. This section of the balefill was regraded during the study period to prevent the ponding of surface water and was then vegetated with a mixture of high grasses.

Filling began in the larger depression in a similar manner and continued until June 1974 when operations stopped. By this time, the balefill had received approximately 4,000,000 m^3 (5,200,000 yd^3) of unprocessed refuse with a total weight of 337,800 tonnes (372,155 tons) and a baled volume of 422,000 m^3 (552,000 yd^3). The average volume per unit area of unprocessed refuse equals 250,000 m^3/ha (130,000 yd^3/ac). The owners decided to continue operations in the larger depression as a disposal site for demolition wastes until the proposed final grade had been attained. Demolition wastes were accepted throughout the study period. This material was spread and compacted with a bulldozer and was covered periodically.

No ponding was evident during the study and no rodents or vectors were observed, although mosquito control had been a problem in some small surface water impoundments around the perimeter of the fill.

Directly adjacent to the southern boundary of the balefill site is a privately-owned sanitary landfill. This is a considerably larger operation which uses the area fill method. It has been completed to a much higher grade than the balefill. Considerable erosion was observed on the slope of the sanitary landfill adjacent to the balefill.

Monitoring Network

The monitoring points at the balefill site were so located that samples could be obtained of leachate and of ground water upgradient of, adjacent to, and downgradient from the balefill. MP #1 and #3 provided leachate samples. MP #1 is part of a leachate collection area that was constructed at the northwest corner of the balefill in 1973 for a previous EPA study. Chemical analyses from this point were the only historical data available. Balefill settlement, leachate production, gas generation, and temperature were monitored. This historical data base, along with the present data, provides an excellent opportunity to monitor full-strength leachate at a balefill. MP #3 is a 0.9 m (3 ft) diameter, 8.8 m (29 ft) deep manhole consisting of several sections of corrugated metal pipe. The joints between the sections were insufficiently sealed and water infiltrates continuously during wet periods. It yielded dilute leachate.

Five wells were used to monitor the balefill during the study period (see Figure 16, Table 6, and Appendix A). One of these was an existing monitoring well (MP #5), and four were new monitoring wells drilled for this study (MP #2, #4, #6, and #7).

MP #5 is located approximately 457 m (1500 ft) southwest of the balefill and provided samples of deep upgradient ground water. It was installed previously to monitor ground-water quality on the property adjacent to the balefill. MP #5 is 69.2 m (227.0 ft) deep and was constructed with 5.08 cm (2.00 in) steel casing. A 1.1 m (3.7 ft) section of 3.18 cm (1.25 in) slotted well screen was fitted to the bottom of the well.

The logs of this well indicate that it penetrated gravel with occasional layers of clay to 31.4 m (103.0 ft), clay to 37.5 m (123.0 ft), fine sand with occasional layers of clay to 64.0 m (210.0 ft), sandstone to 68.6 m (225.0 ft), and limestone to 69.2 m (227.0 ft). A pump was installed in MP #5 in order to facilitate sample recovery, but this made it impossible to measure water levels.

MP #2, #4, #6, and #7 were installed prior to the first sampling round with a mud rotary drilling rig. They were constructed using 10.16 cm (4.00 in) steel casing and 10.16 cm (4.00 in) PVC well screens. Each well was sealed with grout to prevent the infiltration of surface water.

MP #2 is located adjacent to the eastern boundary and directly downgradient of the balefill. It was completed at a depth of 60.4 m (198.1 ft) and the lowermost 6.9 m (22.7 ft) was fitted with 0.025 cm (.010 in) slotted well screen. In

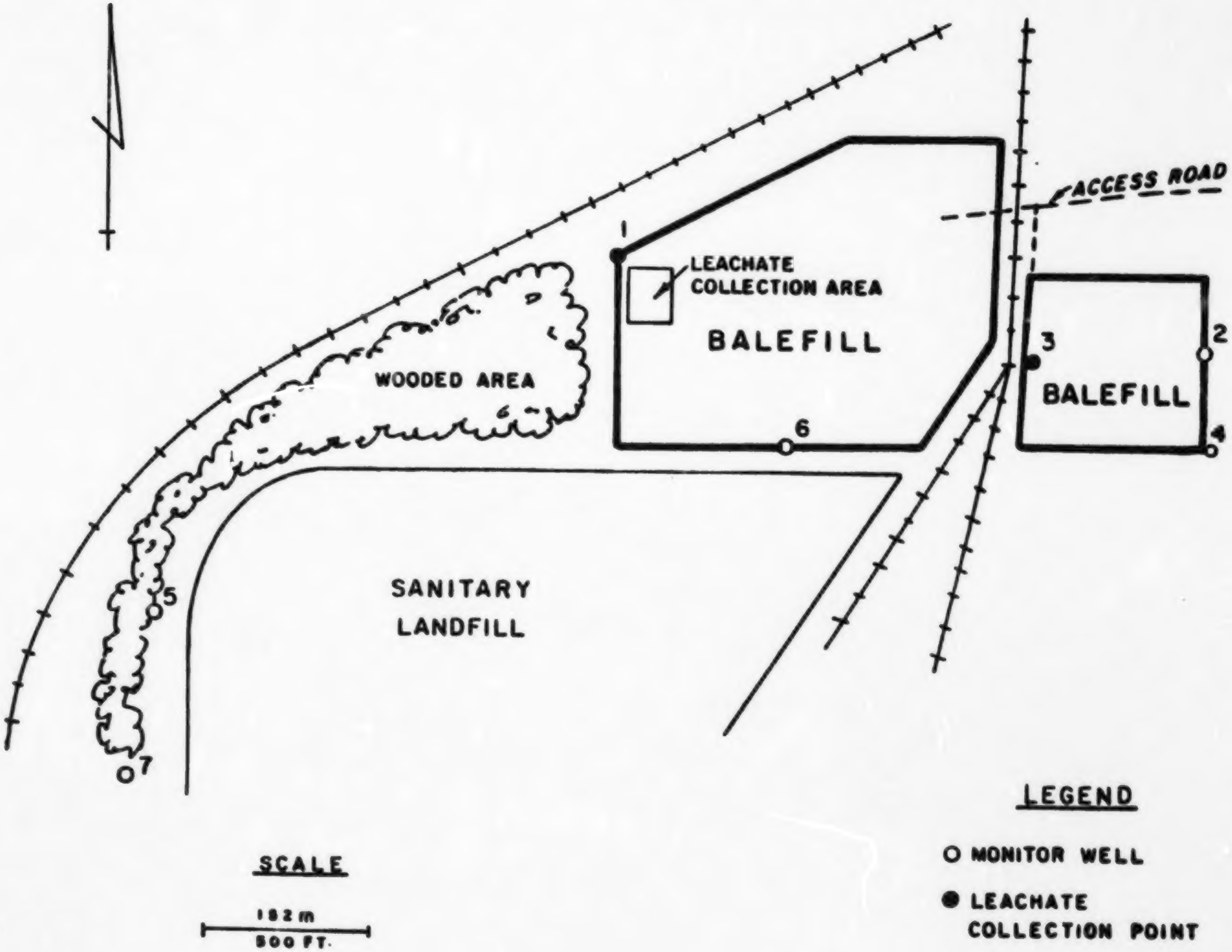

ACCESS ROAD
1
LEACHATE
COLLECTION AREA
BALEFILL
3
2
BALEFILL
4
6
WOODED AREA
5
SANITARY
LANDFILL
7
SCALE
182 m
500 FT.
LEGEND
○ MONITOR WELL
● LEACHATE
COLLECTION POINT

Figure 16. Location of monitoring points at the balefill site.

TABLE 6. MONITOR WELL CONSTRUCTION DETAILS - BALEFILL[a]

					Elevation[c]		
MP #	Well depth	Total[b] casing	Type casing	Section slotted	Top of casing	Reference[d]	Surface elevation
2	60.4 (198.1)	61.3 (201.0)	10.16 cm (4.00 in.) Steel	60.4- 53.5 (198.1-175.4)	274.95 (902.07)	0.89 (2.91)	274.06 (899.16)
4	59.4 (194.8)	60.2 (197.5)	10.16 cm (4.00 in.) Steel	59.4- 53.1 (194.8-174.1)	276.44 (906.96)	0.81 (2.66)	275.63 (904.31)
5	69.2 (227.0)	68.0 (223.0)	5.08 cm (2.00 in.) Steel	68.0- 66.8 (223.0-219.3)	-----[e]	----	268.22 (880.00)
6	52.5 (172.3)	53.3 (174.7)	10.16 cm (4.00 in.) Steel	52.5- 46.2 (172.3-151.6)	270.00 (885.85)	0.73 (2.41)	269.27 (883.44)
7	44.7 (146.7)	45.4 (148.9)	10.16 cm (4.00 in.) Steel	44.7- 38.0 (146.7-124.8)	268.25 (880.09)	0.66 (2.16)	267.59 (877.93)

[a] Measurements in meters (feet) unless otherwise indicated.

[b] Total casing is equal to the casing in the ground plus casing above ground (Reference).

[c] All elevations relative to mean sea level.

[d] Reference above ground surface from which water level measurements are taken.

[e] Dashes indicate information not available.

drilling, the first 3.0 m (10.0 ft) penetrated silt and clay with some sand and gravel, till materials similar to those removed from the surrounding hills and used as cover material. Below 3.0 m (10.0 ft), the sediments consisted primarily of sands and gravels, containing varying degrees of silts and clays. Occasional cobbles were also present.

MP #4 is located near the southeastern corner of the balefill area and also provided downgradient ground-water samples. It was drilled to a depth of 59.4 m (194.8 ft) and fitted with 6.3 m (20.7 ft) of 0.025 cm (.010 in) slotted well screen. The sediments encountered were similar to those found in MP #2, primarily sands and gravels.

MP #6 was emplaced immediately adjacent to the southern boundary of the balefill to monitor ground water passing from the sanitary landfill to the balefill site. It was drilled to a depth of 52.5 m (172.3 ft) and 6.3 m (20.7 ft) of 0.025 cm (.010 in) slotted well screen was fitted to the bottom of the casing. The first 3.0 m (10.0 ft) of drilling penetrated clay and silt fill materials containing some loose refuse. At a depth of 3.0 m (10.0 ft), a layer of clean sand was present indicating the top of the thick sand and gravel deposits; the well was completed in these deposits.

MP #7 is located approximately 610 m (2000 ft) southwest of the balefill and monitors shallower upgradient ground water than does MP #5. It is 44.7 m (146.7 ft) deep and was completed with 6.7 m (21.9 ft) of 0.025 cm (.010 in) slotted well screen. The sediments encountered during drilling were similar to those encountered in MP #2, #4, and #6 consisting primarily of sands and gravels with minor amounts of silt and clay.

Particle Size Analyses

Four samples obtained during the drilling of MP #2 were examined for particle size distribution to better determine the attenuation characteristics of the geologic material (see Appendix B). Although four new wells were drilled during the study period, analyses were conducted only on samples from MP #2. This downgradient monitoring point contains material which appeared visually similar to the thick sand and gravel deposits encountered during the drilling of all four wells. The particle size analyses conducted on samples from MP #2 were therefore used as representatives for all four wells.

Table 7 shows the results of the particle size analyses. All four samples are composed primarily of sand and coarse fragments, size separates that do not effectively adsorb leachate constituents. The higher percentage of silt and

TABLE 7. PERCENTAGE OF SEPARATES BY WEIGHT FOR THE GEOLOGIC MATERIALS AT THE BALEFILL.[a]

Sample description	% Clay	% Silt	% Sand	% Coarse fragments
MP #2 Some till, sand and gravel. 2.1 - 6.4 m (7.0 - 21.0 ft)	7	17	61	15
MP #2 Sand and gravel. 7.5 - 12.5 m (24.5 - 41.0 ft)	1	4	74	21
MP #2 Sand and gravel. 13.6 - 14.0 m (44.5 - 46.0 ft)	4	6	37	53
MP #2 Sand and gravel. 15.1 - 15.5 m (49.5 - 51.0 ft)	1	1	92	6

[a] Size limits for the soil separates are based on the U. S. Department of Agriculture system. The diameter range for separates is:

Clay, less than 0.002 mm
Silt, 0.002 - 0.05 mm
Sand, 0.05 - 2.0 mm
Coarse Fragments, greater than 2.0 mm

clay contained in the shallow sample is probably attributable to the layer of till and till-derived soils penetrated during drilling of this well.

Hydrogeology of the Balefill Site

The balefill is situated in an area of rolling knob and kettle topography. The undulating landscape is a result of glacial action and is associated with moraines. This topography is characterized by numerous isolated depressions and usually exhibits poor drainage.

The balefill was developed on outwash and till overlying stratified drift and alluvial sands and gravels. Bedrock in the study area consists of the Prarie duChien Group, the Jordan Sandstone, the St. Lawrence Formation and the Franconia Formation. Ground water moves down through the unconsolidated materials in complex flow systems created by the intertonguing glacial/alluvial sediments. Recharge to the bedrock aquifer may be direct or via interconnected flow systems in the overlying sediments.

Construction of the balefill drastically altered the natural topography and drainage at the site and so the regional water budget is not applicable. Furthermore, the balefill cover material was graded to a very gentle slope, resulting in a lower runoff component (SW) than that of the region as a whole. A modified water budget based on a previous study and applied to the average regional annual precipitation indicates that, of the average 65.88 cm (25.94 in) of precipitation, 76 percent is lost through evapotranspiration (ET), 5 percent runs off as surface water (SW), and 19 percent recharges the ground water (GW). The water budget can be expressed as:

$$\begin{array}{ccccccc} \text{PPT} & = & \text{ET} & + & \text{SW} & + & \text{GW} \\ 65.88\text{ cm} & = & 50.07\text{ cm} & + & 3.29\text{ cm} & + & 12.52\text{ cm} \\ (25.94\text{ in}) & = & (19.71\text{ in}) & + & (1.30\text{ in}) & + & (4.93\text{ in}) \end{array}$$

The balefill was developed on a 16-ha (39-ac) base which consists of a thin layer of compacted glacial materials. Leachate generation by the balefill can be estimated using the water budget and the area of the balefill base. Multiplying the 12.52 cm (4.93 in)of annual recharge by the 16-ha (39-ac) base of the balefill yields 20,032 m^3 (16.02 ac-ft) per year of potential leachate generation.

Figure 17 shows a cross section of the balefill taken along AA' (shown on Figure 18) and passing from east to west through MP #2 and MP #3. The balefill overlies approximately 10 m (33 ft) of outwash, till, and lacustrine deposits. These sediments overlie approximately 20 m (65 ft) of strati-

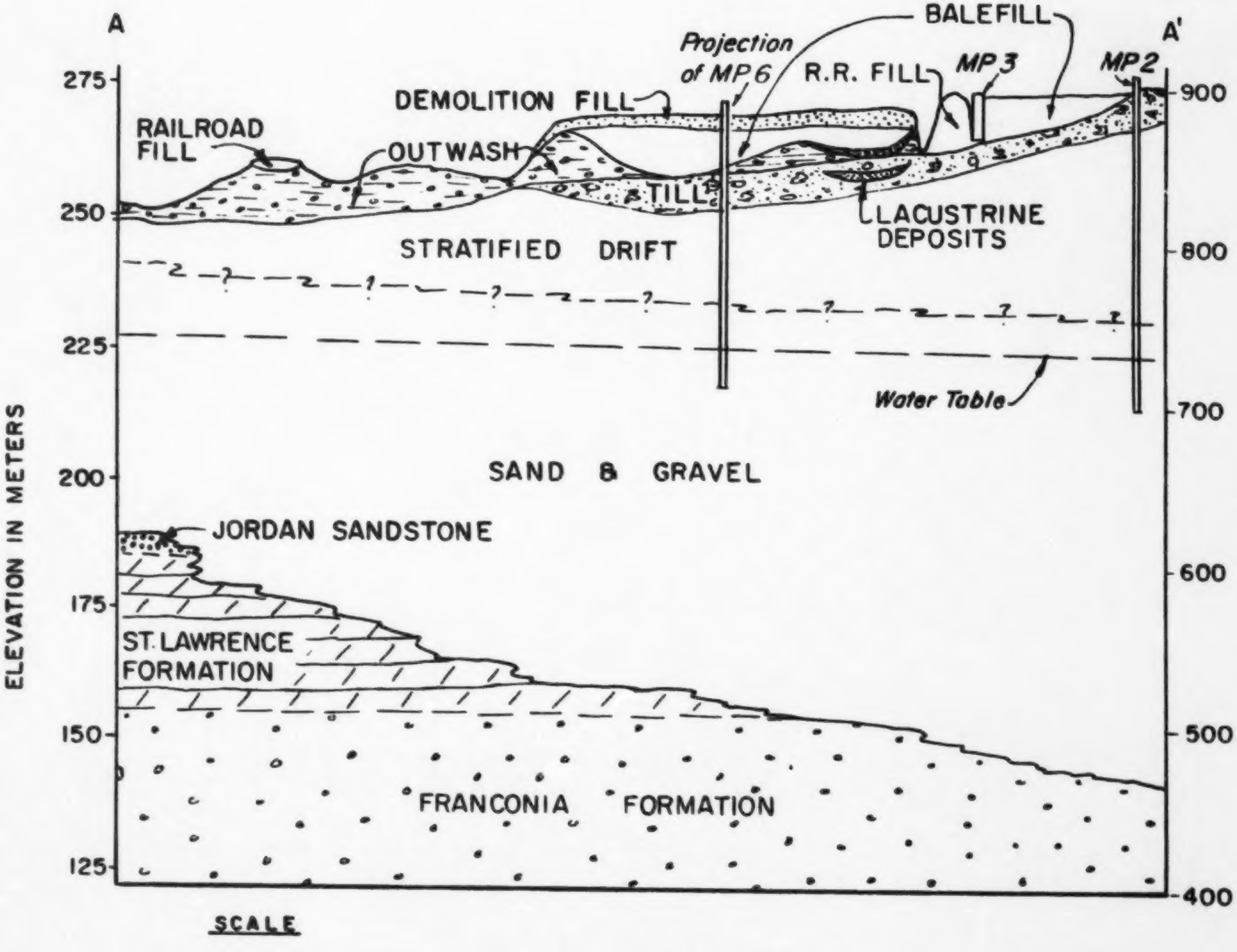

A
A'
BALEFILL
Projection of MP6
R.R. FILL
MP3
MP2
DEMOLITION FILL
RAILROAD FILL
OUTWASH
TILL
LACUSTRINE DEPOSITS
STRATIFIED DRIFT
Water Table
SAND & GRAVEL
JORDAN SANDSTONE
ST. LAWRENCE FORMATION
FRANCONIA FORMATION
ELEVATION IN METERS
275
250
225
200
175
150
125
ELEVATION IN FEET
900
800
700
600
500
400
SCALE
182 m
600 FT.
Vertical Exaggeration 5x

Figure 17. Cross section of the balefill site.

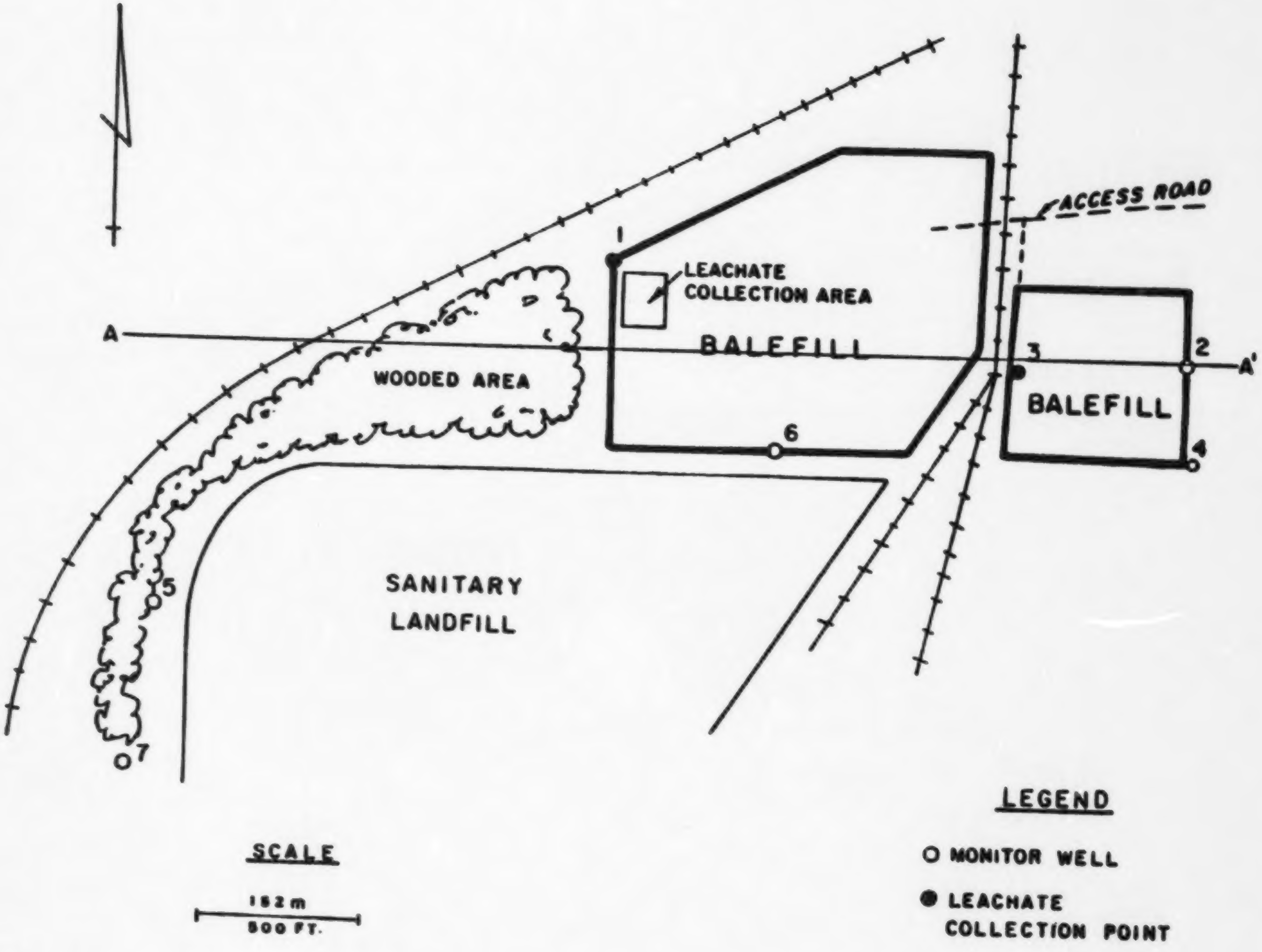

ACCESS ROAD
1
LEACHATE COLLECTION AREA
BALEFILL
A
A'
3
2
BALEFILL
WOODED AREA
6
4
5
SANITARY LANDFILL
7
LEGEND
○ MONITOR WELL
● LEACHATE COLLECTION POINT
SCALE
152 m
500 FT.

Figure 18. Map showing the location of the line of cross section, AA'.

fied drift and approximately 76 m (250 ft) of sand and gravel deposits lie between the stratified drift and bedrock.

Depth to water at the site (see Appendix C) ranged from 33.5 to 51.8 m (110-170 ft). The average seasonal fluctuation in the water table varied between 0.30 and 0.91 m (1.0-3.0 ft). A water table map based on water table elevations from four data points, is displayed in Figure 19. It shows that the regional hydraulic gradient is to the east towards a discharge area that feeds a major river.

The surface of the balefill is situated approximately 43 m (140 ft) above the regional water table. In unsaturated conditions, leachate will be produced only by the percolation of rainfall or snowmelt. The baling of solid waste markedly decreases the permeability of the waste and greatly reduces the surface area available to leaching. The compacted bales have a low moisture retention capacity. The flow of precipitation through the balefill is quite rapid and may be attributed to channel flow between the bales and through fractures within them. Therefore, water moving through the balefill has a short retention time within the fill. However, the leachate produced is dilute since there is little surface area contact and the water is retained within the balefill only a short time.

After leaving the balefill, the leachate flows under unsaturated conditions through the underlying till and outwash. The clay present within the till provides attenuation of pollutants. The outwash on the other hand, has less clay than the till and therefore has a lower potential for pollutant attenuation. The major mechanism for attenuation is the great thickness of consolidated materials which increases the amount of sites available for ion exchange, and biological and chemical degradation processes. Leachate is diluted and dispersed as it percolates through the stratified drift. Ground water in the study area has a very high average velocity and rapidly disperses contaminants that reach the saturated zone.

Water Chemistry at the Balefill Site

There are several factors which influence the chemistry of the ground water in the area of the balefill in addition to the balefill itself. The large sanitary landfill that lies to the south and southwest of the balefill has impacted the ground water upgradient of the balefill (see Figure 13). Industry farther south and agricultural activity to the north and west also may affect the ground water entering the balefill area. MP #6, located between the sanitary landfill and the balefill, provides an indication of the effect of

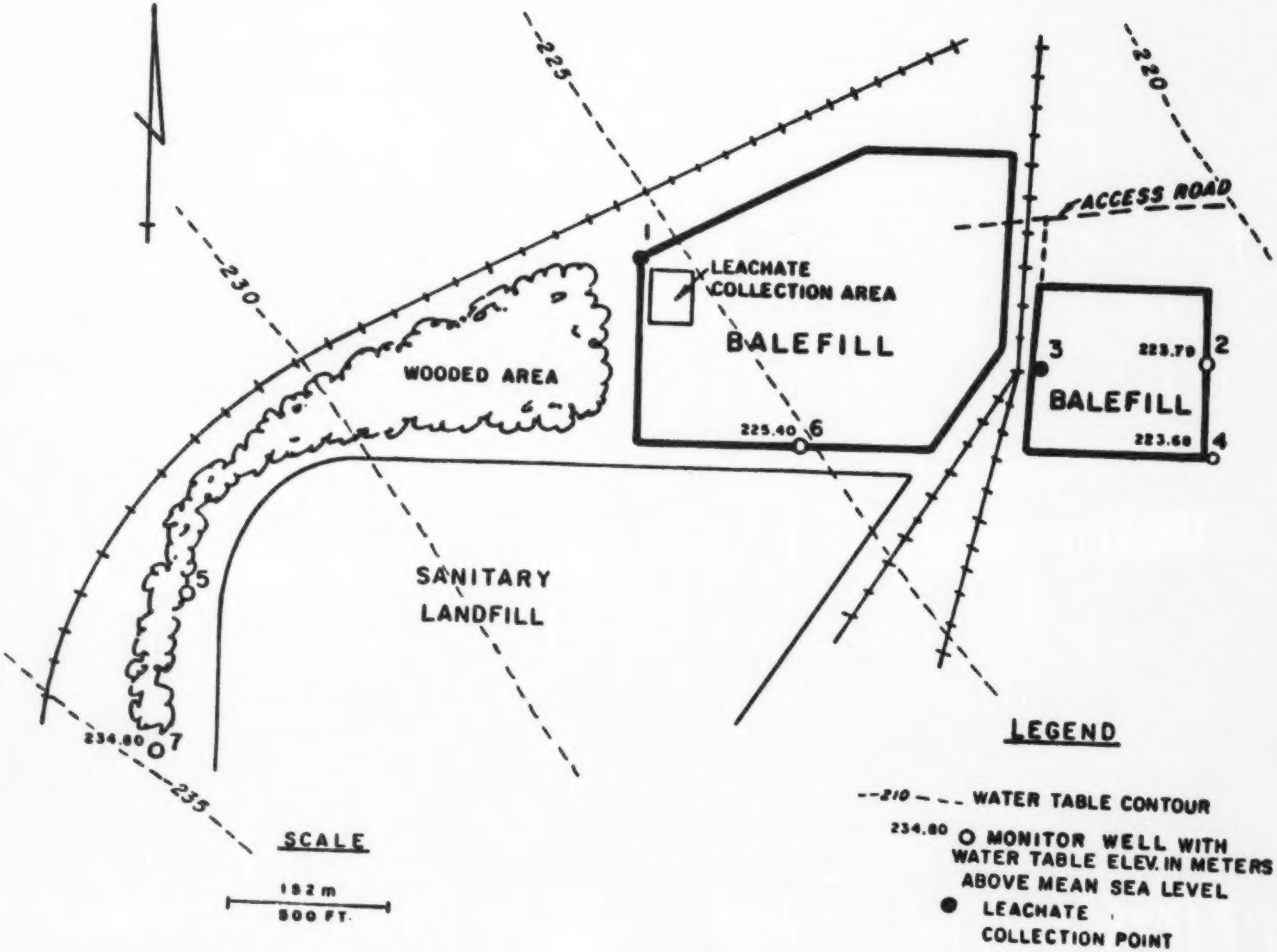

220
ACCESS ROAD
225
230
235
1
LEACHATE COLLECTION AREA
BALEFILL
WOODED AREA
225.40
6
3
2
223.70
BALEFILL
223.60
4
5
SANITARY LANDFILL
234.80
7
SCALE
152 m
500 FT.
LEGEND
210 WATER TABLE CONTOUR
234.80 ○ MONITOR WELL WITH WATER TABLE ELEV. IN METERS ABOVE MEAN SEA LEVEL
● LEACHATE COLLECTION POINT

Figure 19. Map of water table at the balefill site.

the sanitary landfill on ground water prior to its passage beneath the balefill area.

MP #5 and #7 provide samples of background water adjacent to the sanitary landfill. MP #5 is seated in the Jordan Sandstone, the major aquifer in the area, and the lowermost 0.9 m (3 ft) of the casing is screened so that samples from this well reflect only this portion of the bedrock aquifer. Only two samples were obtained from this well; samples were not obtainable in January and July because a generator was not available to operate the pump. MP #7 monitors shallow background ground water within the unconsolidated sediments. Samples from this well have slightly elevated concentrations for many of the parameters analyzed relative to those from the deep background well; these analyses reflect the impact of local agriculture, industry, and the sanitary landfill.

The two downgradient wells provide samples of ground water directly beneath and adjacent to the balefill (MP #2) and ground water 6 to 10 m (20-30 ft) east of the balefill (MP #4). In addition, MP #4 is not in the direct ground-water flow path. The location of these wells, sampled during all four sampling rounds, allows assessment of the dilution and dispersion capacity of the aquifer.

Leachate was sampled in both portions of the balefill at MP #1 and #3. MP #1 was not sampled during January because of a large accumulation of snow over the monitoring point. MP #3, the dilute leachate in the manhole, was sampled with a bailer during January, April, and July.

Bar graphs, constructed using mean concentrations of alkalinity, acidity, TDS, TKN, COD, and TOC, are shown on Figures 20, 21, and 22; also, see Appendix E and Section 2. These graphs show that during the study period, the balefill produced a leachate (MP #1) of moderate strength but that the concentration of contaminants decreased rapidly from within the balefill to the periphery; concentrations of parameters in both downgradient wells (MP #2 and #4) are frequently below the maximum contaminant levels (MCLs) for drinking water.

The bar graphs for alkalinity and acidity (see Figure 20) are very similar to each other. The deep background well (MP #5) has a mean value of 84 mg/l for alkalinity and -74 mg/l for acidity. The shallow background well (MP #7) has higher values of alkalinity (238 mg/l) and lower acidity (-259 mg/l). Values for the leachate at MP #1 are high with alkalinity of 2,730 mg/l and acidity of -2,553 mg/l. The dilute leachate (MP #3) has values for alkalinity and acidity of 416 and -456 mg/l, respectively.

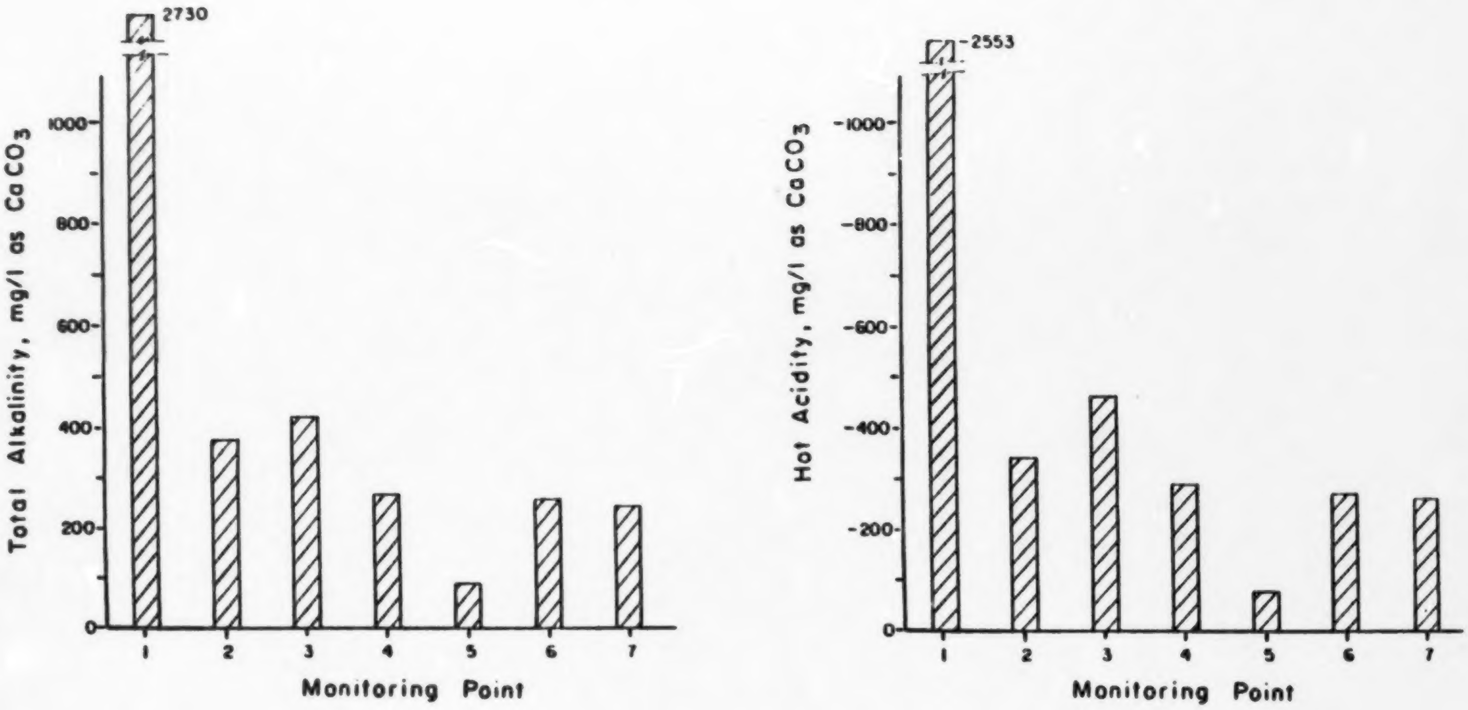


Figure 20. Bar graphs for alkalinity and acidity at the balefill site.

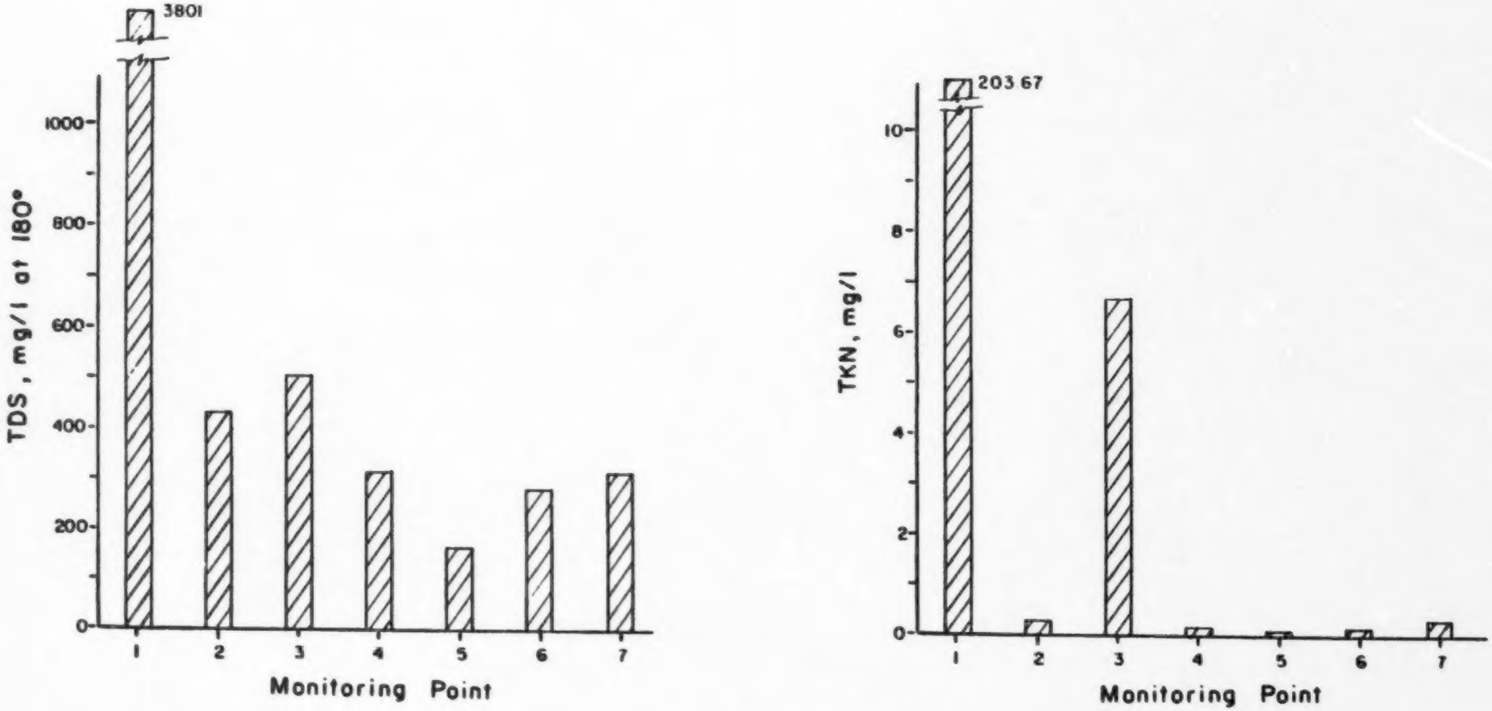


Figure 21. Bar graphs for TDS and TKN at the balefill site.

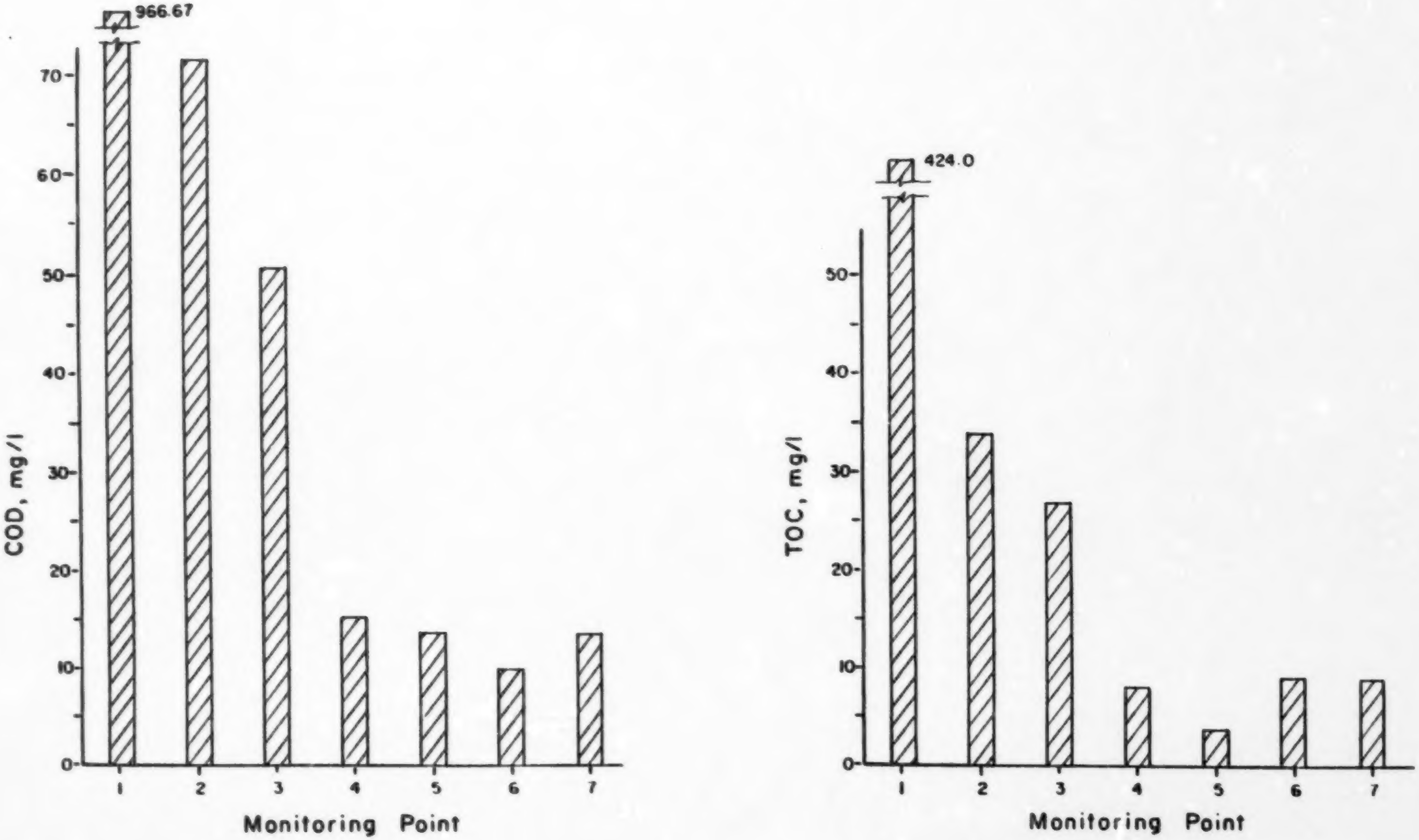


Figure 22. Bar graphs for COD and TOC at the balefill site.

MP #6 has values for alkalinity of 257 mg/l and acidity of -265 mg/l; these are slightly higher than the values of the shallow background well, MP #7. The downgradient well, MP #2, has levels slightly lower than those for MP #3 but nearly one order of magnitude lower than those for the leachate (MP #1); alkalinity averages 370 mg/l and acidity -337 mg/l. MP #4, which is out of the direct flow path, and hence less influenced by pollutant migration from the balefill shows a still lower value of 259 mg/l alkalinity and a less negative value of -283 mg/l acidity which are only slightly elevated above the shallow background level. The relationship between MP #2 and #4 shown by these parameters indicates that contamination decreases rapidly with increasing distance from the balefill.

The histograms for TDS and TKN are shown on Figure 21. The bar graphs for TDS show the same relationships between monitoring points as do the graphs of alkalinity and acidity. MP #5 has the lowest value of 162 mg/l and MP #7 has a slightly higher concentration of 315 mg/l. The leachate (MP #1) has elevated concentrations averaging 3,801 mg/l and the dilute leachate (MP #3) has a value of 499 mg/l.

TDS in MP #6 averages 281 mg/l, slightly lower than the background well, MP #7. Downgradient well MP #4 averaged 311 mg/l which is also below the shallow background level. The difference in values among these three wells, however, is not statistically significant; their values are similar to each other. TDS in MP #2 (424 mg/l) is elevated above background levels but is an order of magnitude lower than that in MP #1 and is slightly lower than the dilute leachate, MP #3. MP #5, #7, #6, and #4 all showed concentrations of TDS consistently below the MCL (500 mg/l); MP #2 had a mean value below the MCL but slightly exceeded that value on the first and last sampling rounds (see Appendix E).

Alkalinity, acidity, and TDS provide a general indication of the quality of the ground water and measure primarily the inorganic fraction of contamination. The next three parameters to be discussed, TKN, TOC, and COD, provide insight into the behavior of organic compounds in the ground water. Comparison between these two groups of parameters shows that different patterns exist.

TKN (see Figure 21) is present only in trace amounts in the background well, MP #5 (0.09 mg/l) but is higher in the shallow background well, MP #7 (0.31 mg/l). TKN in the leachate, MP #1, is elevated, 203.67 mg/l, and the dilute leachate averaged 6.59 mg/l. MP #2, #4, and #6 all had low TKN values; MP #6 averaged 0.11 mg/l, MP #2 averaged 0.25 mg/l, and MP #4, slightly lower, averaged 0.16 mg/l. The levels of TKN in the wells were at least 3 orders of magnitude lower than that in the leachate at MP #1.

The graphs of COD and TOC are shown on Figure 22. These graphs are similar to each other but quite different from the preceding graphs. The levels of COD in the background wells (MP #5 and #7) were similar to each other with values of 13.45 mg/l and 13.23 mg/l, respectively. The leachate (MP #1) is high, 966.67 mg/l, with MP #3 nearly an order of magnitude less, 50.33 mg/l.

COD in MP #6, 9.73 mg/l, is below background levels; the difference, however, is less than one standard deviation. Although MP #4 is a downgradient well, it has a concentration slightly greater than the background with a value of 15.00 mg/l since it is out of the direct flow path. In contrast to the relationships between monitoring points discussed in the preceding graphs, the bar graph for COD shows that MP #2, adjacent to the balefill, has a COD value of 71.50 mg/l, which is elevated even above the dilute leachate at MP #3.

The bar graph for TOC is similar to that for COD. TOC is low in the background wells, MP #5 and #7, 3.4 and 8.6 mg/l respectively. TOC in the leachate is high, 424.0 mg/l, and is much lower in the dilute leachate at MP #3 (26.3 mg/l). MP #6 has a level of TOC similar to the background level (8.8 mg/l). MP #4 is slightly lower with a value of 7.9 mg/l, showing that it is less influenced by the balefill. As was the case with COD, TOC concentrations in MP #2 are quite elevated compared to the other wells and are also higher than that at MP #3. MP #2 showed a mean value of 33.6 mg/l which is an order of magnitude lower than that of MP #1.

In summary, the bar graphs illustrate that there is a rapid decrease in concentrations of contaminants with increasing distance (vertical and horizontal) from the balefill. This is evidenced in the decrease of parameter concentrations between the leachate and MP #2 (at the periphery of the balefill) and is further evidenced by the decrease between MP #2 and #4 (which is adjacent to the balefill but is out of the direct flow path of contaminants movement from the balefill). As the leachate moves down through the unsaturated zone in the glacial sediments, ions are adsorbed by clay minerals. When leachate enters the ground water beneath the balefill site, it is diluted and dispersed. The bar graphs for alkalinity, acidity, and TDS show that a large portion of the ions in the leachate have been attenuated by the time the leachate reaches the ground water at MP #2. Since MP #4 receives contaminants through lateral migration, ionic concentration at MP #4 is even closer to that in the background ground water.

The bar graph for TKN shows that levels of organic nitrogen are high in the leachate but, as leachate moves through more than 30 m (100 ft) of sediment down to the water table, the organic nitrogen is oxidized and degraded.

The histograms for COD and TOC indicate that the organic compounds in the leachate are diminished in a slightly different manner from the inorganic material (shown by alkalinity, acidity, and TDS). Concentrations of organics at MP #2 are significantly higher than they are at MP #4; the difference in concentrations of organics between these two monitoring points is greater than the difference shown by alkalinity, acidity, and TDS between these monitoring points. As the leachate passes from the balefill into the underlying sediment, it appears that the exchange sites on the clay are quickly saturated with ions from organic compounds and the clay therefore ceases to attenuate the leachate; thus organics continue to percolate down through the coarse sediment toward the water table. As they are not significantly attenuated by clay, the degradation of these organics is primarily a function of chemical oxidation and biological degradation before they reach the water table. The concentration of the organic compounds in the ground water at MP #2 is relatively high. The level of organic compounds at MP #4 is similar to that in the background wells.

The bar graphs indicate that the impact of the balefill on the ground water has been relatively limited in magnitude and extent.

The Stiff diagrams (see Figure 23) are graphical illustrations of the mean concentrations of the parameters of sodium, iron, manganese, zinc, chloride, sulfate, nitrate, and phosphate in the various wells and leachate. The diagram for the deep background well (MP #5) shows some sodium, iron, zinc, chloride, and sulfate and relatively little manganese, nitrate, and phosphate. The shallow background well (MP #7) shows a shape similar to that of MP #5 except that nitrate is higher and zinc is lower. This indicates that the water quality at MP #5 and #7 may have been influenced by the adjacent sanitary landfill. The nitrate value for MP #7 is so much greater than that for any of the other monitoring points, including the leachate, that it suggests that MP #7 has been affected by the local agriculture to the west.

The leachate at MP #1 is elevated relative to the background monitoring points in sodium (100 times), iron (10 times), chloride (100 times), and sulfate (100 times). Manganese, zinc, and phosphate are present in significant amounts but nitrate is low because of the reducing environment. The dilute leachate at MP #3 shows much lower amounts

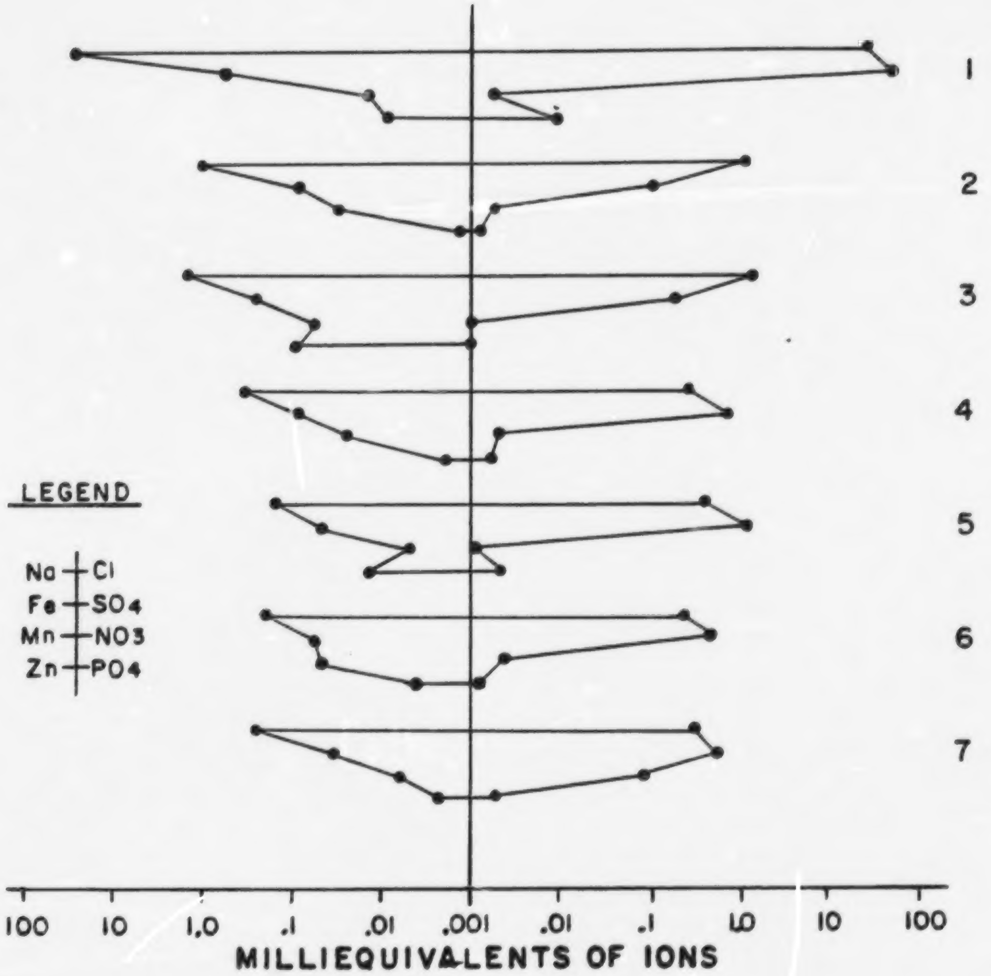


Figure 23. Modified stiff diagrams showing averaged results of chemical analyses at the balefill site.

of sodium, iron, and chloride than MP #1 but is still higher than background. Sulfate is less than the background level and nitrate and phosphate were present only in trace amounts. Manganese and zinc levels are even higher than those of the leachate at MP #1. A high manganese value is also seen in MP #6 and the two downgradient wells (MP #2 and #4) and may be attributable to the bog sediments which collected in the kettle lakes beneath the balefill site. The high zinc value in MP #3 may be caused by the galvanized steel pipe used to construct the manhole.

The diagram for MP #6 has a shape similar to that of the shallow background well (MP #7) except for manganese which is higher and nitrate which is lower. MP #2 is slightly higher than MP #7 in sodium, iron, manganese, and chloride and lower in zinc, nitrate, and phosphate. The diagram for MP #4 shows greater amounts of sulfate but otherwise has a shape similar to that of the other downgradient well (MP #2).

The trends seen in these parameters are that sodium, iron and chloride concentrations decrease with distance from the balefill and that sodium attenuates more rapidly than iron. Sulfate and phosphate are highest in the leachate but show no consistent relationship among the wells. Manganese and zinc levels are largely unrelated to the balefill. The Stiff diagrams confirm that the impact of the balefill is localized.

The nitrogen ratios for both the leachate and groundwater monitoring points are illustrated in Figure 24. They confirm the relationships seen in the bar graphs of the organic parameters; the balefill is a source of reduced compounds and concentrations of these chemicals decrease rapidly with movement away from the fill.

Leachate at MP #1 has the highest ratio, 1,903. The ratio for MP #3, the 0.9 m (3 ft) diameter manhole, is lower, with a value of 388, primarily because of the dilution by rainwater and the availability of oxygen (contact with the atmosphere) which allows increased oxidation of reduced nitrogen species. The ratio in the ground water at MP #2 is sharply decreased (2.23) indicating further oxidation. The reduced nitrogen is decreased further (ratio of 1.31) at MP #4 by dilution and dispersion. MP #6, which reflects the effect of the sanitary landfill, is still less (0.81).

The nitrogen ratios at the two background wells may be misleading. MP #5 has the second highest ratio among all the wells (1.50) but the actual amounts used to derive this value are very small. Actual amounts are somewhat greater for MP #7, but the relatively high amount of nitrate, which probably results from agriculture to the west, causes the ratio to be small (0.06).

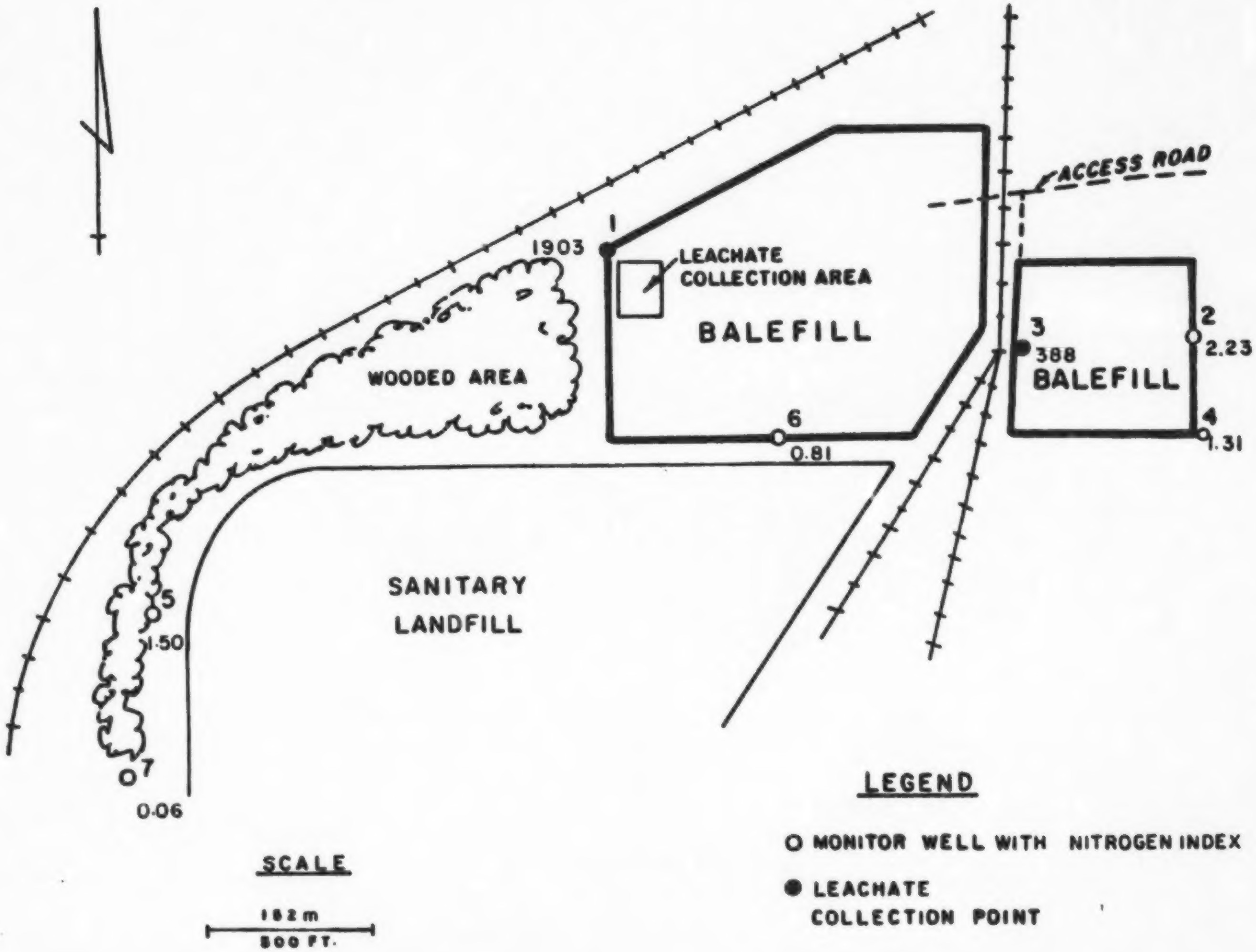

ACCESS ROAD
1
1903
LEACHATE COLLECTION AREA
BALEFILL
WOODED AREA
6
0.81
3
388
BALEFILL
2
2.23
4
1.31
5
1.50
7
0.06
SANITARY LANDFILL
LEGEND
O MONITOR WELL WITH NITROGEN INDEX
● LEACHATE COLLECTION POINT
SCALE
182 m
500 FT.

Figure 24. Nitrogen index showing the ratio of organic nitrogen plus ammonia nitrogen (TKN) to nitrite plus nitrate nitrogen (NO_2 + NO_3).

Historical data is available only for the leachate (MP #1, see Appendix D). Most of the parameters monitored for the present study were included in former studies; a continuity of trends is apparent among the different sets of data. Data is available from late March 1974, shortly after bales were emplaced in this portion of the balefill site, to the end of November 1974 and from early November 1976 to mid-March 1978.

Alkalinity has been rising since the end of 1976 so that concentrations have doubled during the last two years (including the current study, 1979-1980); the low values from the end of 1976 through the first half of 1977 are probably a function of low precipitation during that period. Specific conductance has been rising; there are some signs of it stabilizing during the present study. Chlorides were elevated in 1974, dropped sharply in 1976-77, and rose during the present study to twice their initial value.

TOC and COD have been gradually rising with occasional fluctuations from the norm. TDS has increased in a similar manner. TKN, including ammonia nitrogen and organic nitrogen from the 1974 study, has risen steadily to approximately 10 times its initial value by the close of the present study.

BOD is one of the few parameters that has shown decreasing concentrations with time. A general downward trend was interrupted in the second half of 1977 by the presence of animal activity (habitation) around the monitoring point.

Most metals were present in only small amounts, frequently below detection, and generally did not show a coherent trend. Sodium was low during the dry months at the end of 1976 and early 1977, rose to peak six months later, and returned to its original level during the present study. Magnesium decreased by 50 percent from elevated levels. Calcium is elevated but has shown no consistent trend.

Most parameters showing consistent trends appear to have values gradually increasing with time or to have shown signs of stabilization at the last sampling round of the present study; the contamination potential of the balefill shows little sign of decreasing after approximately six years (for this particular portion of the site). BOD is one of the few decreasing parameters; its downward trend may be attributable to a peak in biological activity within the balefill.

Based on the results of the study, it is concluded that the balefill is having a localized and limited effect on ground water in the vicinity of the site. This is due to the combination of attenuation and dilution and to the fact that the base of the balefill is approximately 30 m (100 ft) above the water table allowing both time and distance to further minimize adverse impacts. The leachate generated by the balefill (MP #1) has been gradually increasing in concentrations or stabilizing except for BOD which has exhibited a downward trend. Thus the contaminant potential of the site has not been significantly reduced in a six year period. This fact confirms the generally accepted concept that a balefill will produce a moderate to low strength leachate over long periods of time.

MILLFILL

The technique of shredding and milling is intended to render solid waste more manageable. This technique has many of the same advantages as the baling process. Refuse is shredded into relatively small pieces and is more economically transported. Shredding minimizes odors and blowing papers; most importantly, refuse can be packed more densely into a given volume. The recovery of metal and other resources also becomes more feasible with the use of this process.

Topographic Position

The millfill lies within the northern glaciated section of the Appalachian Plateau physiographic province. Glacial ice and subsequent erosion and deposition modified the preglacial bedrock topography into its present form. The area is characterized by high local relief with numerous rounded hills interspersed with stream and river valleys. Glacial features form low rolling hills within the valleys and on gently sloping bedrock surfaces.

The millfill is situated on the lower slope of a ridge that grades to the broad floodplain of a major river lying approximately 610 m (2000 ft) to the south of the landfill and flowing in an easterly direction (see Figure 25). The river is fed by numerous tributaries flowing from the surrounding highlands.

Native vegetation in the area consists of woodlands. South of the millfill, the floodplain has been developed for agriculture. The millfill site was stripped of vegetation and its northern unfilled portion is now covered with grasses and weeds. The southern working portion of the site has not been reseeded.

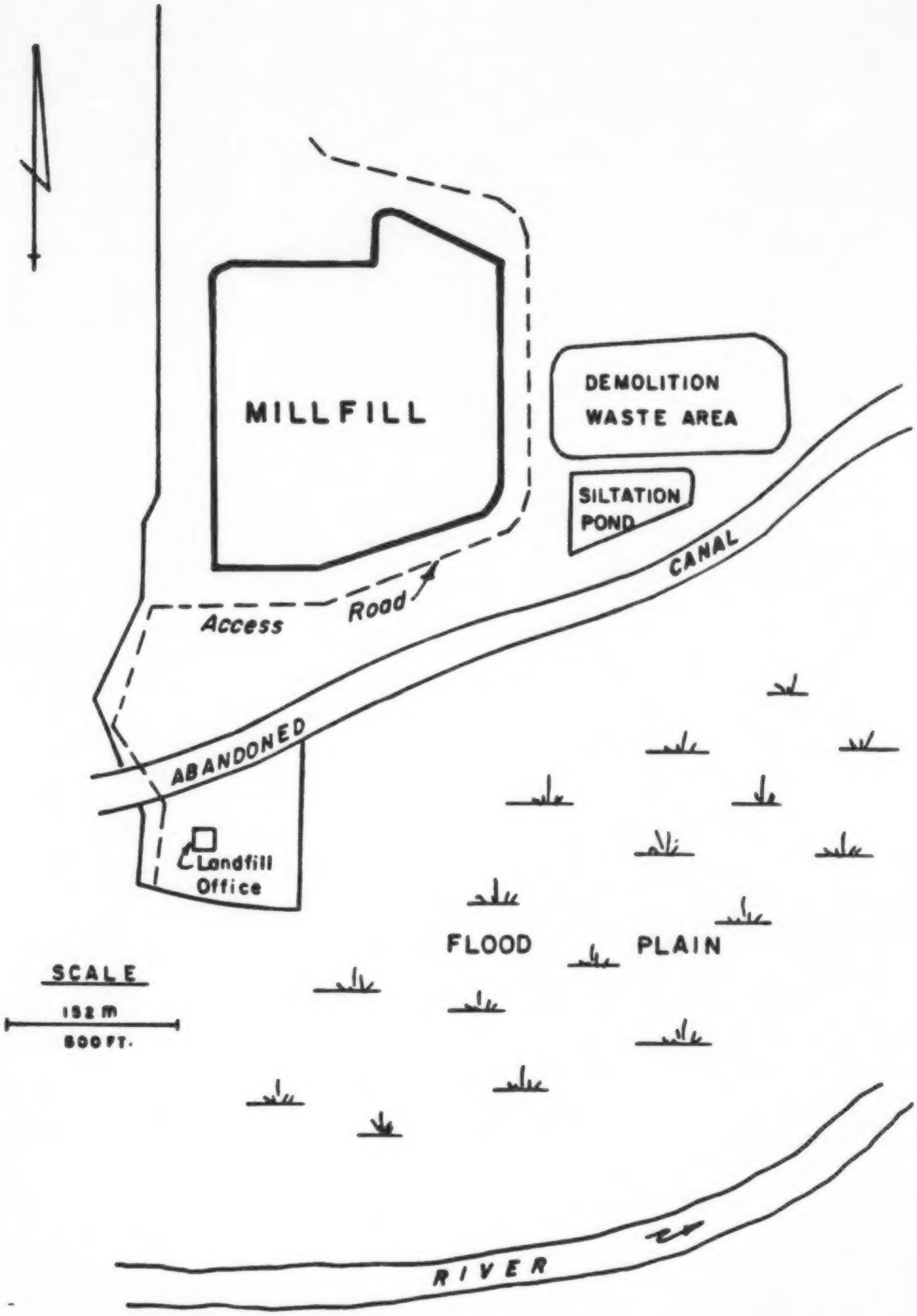

MILLFILL
DEMOLITION WASTE AREA
SILTATION POND
Access Road
ABANDONED CANAL
Landfill Office
FLOOD PLAIN
SCALE
152 m
500 FT.
RIVER

Figure 25. Map of the millfill site.

Climate

The climate at the millfill is humid continental and is characterized by relatively dry, cold winters and warm to hot, wet summers.

On the basis of data compiled by the U. S. Weather Bureau at a nearby weather station for a 30-year period of record, the mean annual precipitation for the millfill area is 83.69 cm (32.95 in) and is evenly distributed throughout the year. The normal monthly low occurs in January with 4.65 cm (1.83 in) and the normal high in May with 9.75 cm (3.84 in), see Figure 26 and Table 8 . January and February are the driest months with average precipitation of less than 5 cm (2 in). May through August is the wettest period with each month averaging greater than 7 cm (3 in) of precipitation. Precipitation during the winter months consists of snow and rain depending on variations in temperature.

Precipitation during the one-year study period was 0.06 cm (0.02 in) above normal. Monthly departures from normal were minimal with the exceptions of November 1978, average of more than 2.5 cm (1 in) below normal, and January 1979, average of more than 5 cm (2 in) above normal.

The mean annual temperature for the millfill area is 8.9 C (48.1 F) with a normal low of -3.9 C (25.0 F) occurring in January and a normal high of 21.6 C (70.8 F) in July.

Geology and Soils

The millfill is underlain by bedrock of Upper Devonian age which is commonly mantled by glacial and fluvial deposits. Bedrock beneath the site has been mapped as both the Gardeau Formation, which consists of silty grey and greenish-grey shales, grey siltstones, and brown to greyish-black shales, and the Roricks Glen Shale, dark grey and black shales with some thin calcareous siltstones. The bedrock in the region has been very gently folded; dips range from horizontal to less than 5 degrees.

The bedrock at the site is overlain by approximately 15 m (50 ft) of glacial outwash, fine-to coarse-grained sands and gravels (see Figure 27). The silt and clay content varies but is usually minor. Since the outwash is composed of coarse-grained material, it is comparatively permeable.

Some silt deposits (silt and fine sand) overlie the outwash at central and northern locations of the site. These silts are believed to have been deposited in lakes formed by dammed ice as the glacier receded. They range from approximately 1.5 to 6 m (5 to 20 ft) in thickness.

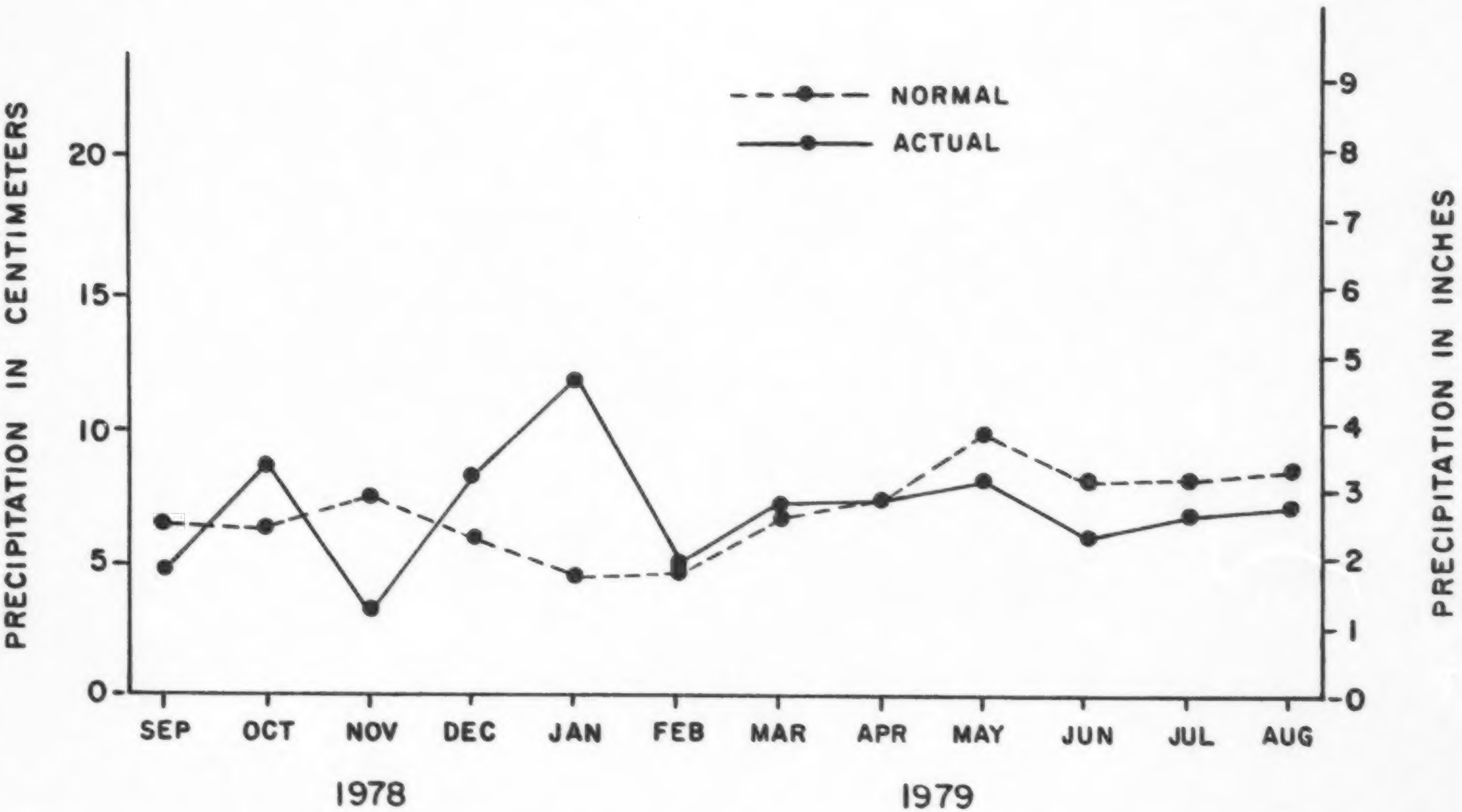


Figure 26. Graph of precipitation at the millfill.

TABLE 8. MONTHLY PRECIPITATION DATA[a] - MILLFILL

Date	Normal	Actual	Departure from normal
9/78	6.48 (2.55)	4.80 (1.89)	-1.68 (-0.66)
10/78	6.38 (2.51)	8.76 (3.45)	2.39 (0.94)
11/78	7.54 (2.97)	3.25 (1.28)	-4.29 (-1.69)
12/78	5.94 (2.34)	8.31 (3.27)	2.36 (0.93)
1/79	4.65 (1.83)	11.63 (4.58)	6.99 (2.75)
2/79	4.75 (1.87)	4.83 (1.90)	0.08 (0.03)
3/79	6.58 (2.59)	6.91 (2.72)	0.33 (0.13)
4/79	7.39 (2.91)	7.39 (2.91)	0.00 (0.00)
5/79	9.75 (3.84)	8.05 (3.17)	-1.70 (-0.67)
6/79	7.87 (3.10)	5.92 (2.33)	-1.96 (-0.77)
7/79	8.13 (3.20)	6.81 (2.68)	-1.32 (-0.52)
8/79	8.23 (3.24)	7.09 (2.79)	-1.14 (-0.45)
TOTAL	83.69 (32.95)	83.75 (32.97)	0.06 (0.02)

[a] Measurements in cm (in)

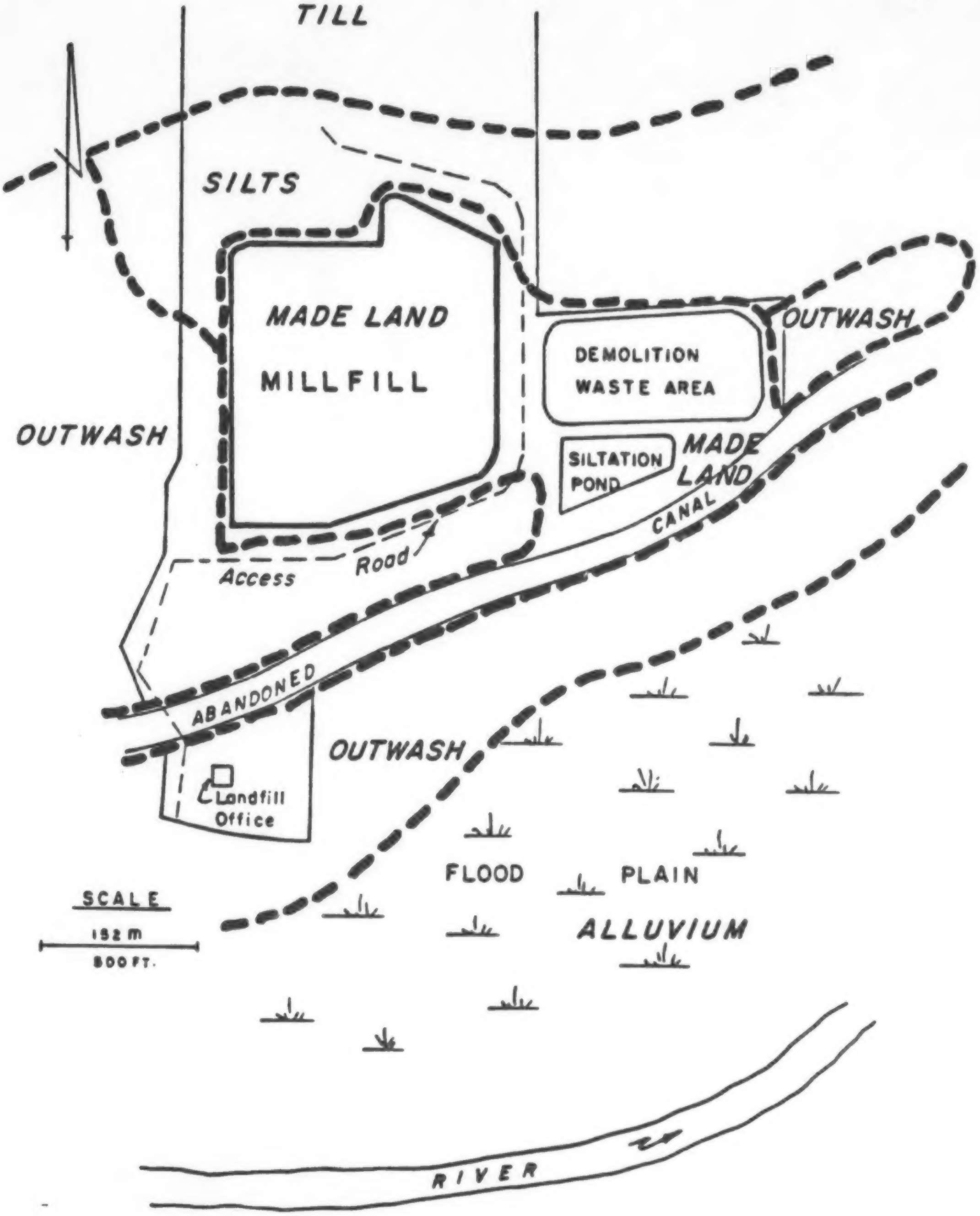

TILL
SILTS
MADE LAND
MILLFILL
OUTWASH
DEMOLITION
WASTE AREA
OUTWASH
SILTATION
POND
MADE
LAND
CANAL
Access
Road
ABANDONED
OUTWASH
Landfill
Office
FLOOD
PLAIN
ALLUVIUM
SCALE
152 m
500 FT.
RIVER

Figure 27. Map of surficial geology at the millfill site.

Deposits of glacial till at least 9 m (30 ft) thick mantle the higher ridges in the northern portion of the site. This till is composed of brown silt with fine sands, gravels, and boulders; it is dense and has low permeability as it was compacted by glacial ice. Well-stratified, variously-textured alluvial sediments lie in the floodplain of the river south of the site.

Soils at the millfill site were mapped by the USDA Soil Conservation Service prior to filling operations. The original soils at the millfill were excavated and used during site preparation.

The predominant soils in the vicinity of the millfill were formed from glacial till and outwash. Valois gravelly loam is a deep, well drained, moderately permeable soil formed from gravelly glacial till and is found on gentle slopes. Howard gravelly silt loam is a deep, well drained, moderately rapid to rapidly permeable soil formed from stratified sandy and gravelly glacial outwash and is found on nearly level areas to very steep slopes.

To the north of the millfill on the ridge is soil formed in dense glacial till. This soil is Volusia channery silt loam, a deep, somewhat poorly drained soil with slow permeability. To the south of the millfill is a large area of deep, well drained, moderately rapidly permeable soil formed from silty and fine sandy alluvial deposits on level land. These soils are Unadilla silt loam, Tioga silt loam, Tioga fine sandy loam, and a variably textured, unconsolidated alluvium described as Alluvial Land.

Landfill Operations

The millfill, owned and operated by the County in which it is situated, began operations in December 1973. The entire site covers 57 ha (140 ac); milled refuse was landfilled in the southern portion of the site in an area of approximately 7 ha (18 ac), see Figure 25 and operations will expand eventually into the northern portion of the site. The landfill serves a population of 116,000 accepting municipal refuse, some industrial (non-hazardous) wastes, and demolition wastes. The demolition wastes are landfilled separately in the southeastern portion of the site. Approximately 181 tonnes (200 tons) of refuse are landfilled each day, 6 days per week.

Solid wastes are initially delivered to a nearby facility where large metal objects are separated by hand; these objects are later transported to the demolition waste area at the millfill site. The remaining refuse is shredded to a maximum size of 8 cm (3 in) and is compacted into transfer trailers and transported to the millfill.

In December 1973, landfilling began in an abandoned gravel pit with an approximate area of 0.8 ha (1.9 ac) in the southwestern corner of the millfill. The pit was lined with 2.4 m (8 ft) of materials including vegetation from the clearing of the pit area, excess spoil from the pit access road excavation and bank material from the pit walls. These were covered with an additional 0.6 m (2 ft) of glacial till from the northern portion of the site. Refuse cells 1.5 m (5 ft) high and 34 m (110 ft) long were constructed by the ramp sanitary landfill method until the entire depression was filled with one 1.5 m (5 ft) lift. Two additional 2.4 m (8 ft) lifts were constructed above the initial one. Daily cover material was obtained from the pit area. Upon completion of the three lifts, an intermediate cover (30 cm, 12 in) was emplaced.

Operations in the southwestern corner of the site continued for approximately three years at which time landfilling proceeded to the eastern and then northern portions of the site. These areas were landfilled using the trench method where cover material both for these areas and the demolition waste area was excavated and the excavation filled with refuse. During initial preparation, the millfill base was graded (2 percent) toward the siltation pond at the southeast. After an initial 2.4 m (8 ft) lift was constructed in this manner, successive lifts were constructed by the area lift method.

In general, daily operations consist of the construction of one refuse cell approximately 2.4 m (8 ft) high, 9 m (30 ft) wide, and 22 m (72 ft) long. Refuse is compacted by bulldozer in 30 cm (12 in) layers until the 2.4 m (8 ft) height is reached. The average density of the milled refuse is 653 kg/m^3 (1,100 lb/yd^3). Cells are covered each day with a compacted depth of 15 cm (6 in) of cover material. If an area is left uncovered by additional cells for more than two months, 30 cm (12 in) of intermediate cover is applied.

In January 1979, midway through the study period, an explosion in the milling facility caused shredding operations to cease. Prior to this event, approximately 283,200 tonnes (312,000 tons) of milled refuse had been landfilled at the site; approximately 34,500 tonnes (38,000 tons) of unmilled refuse were landfilled from January 1979 through August 1979 (the end of the study period).

Final grade has not yet been attained; both the millfill and the demolition waste area will have a final grade of approximately 6 percent in the direction of the siltation pond (southeast and downgradient of the millfill). Drainage ditches surround the millfill and grade toward the siltation pond; any leachate seeping from the sides of the millfill would be carried with surface runoff to the ditches and ultimately to the siltation pond.

During the study period, the site appeared to be well operated and in good condition. No vectors or odors were observed. There was an occasional problem with blowing plastic wrappers. During wet periods, occasional leachate seeps were reported on the southern and eastern sides of the millfill; leachate was observed and sampled only once during the study period.

Monitoring Network

Monitoring points were located in order to obtain samples of upgradient ground water, downgradient ground water, and leachate generated by the millfill. Five observation wells, a water supply well, a spring and a leachate seep were used in this study and were designated as MP #1 through #8 (see Figure 28, Table 9, and Appendix A). Historical chemical analyses were obtained for MP #1 through #5.

MP #8, the leachate seep, was present on the southern border of the millfill and was observed and sampled only once during the study period. MP #3, a natural spring, is located in glacial silts north of the millfill. It was used in this study to monitor shallow ground-water quality upgradient from the millfill.

MP #4, drilled in 1974, is an observation well located adjacent to the natural spring and was used to monitor upgradient ground water. It was drilled to 6.1 m (20.0 ft) and was completed at 3.7 m (12.0 ft) because of caving. Glacial outwash was encountered to a depth of 1.5 m (5.0 ft) and was underlain by 4.6 m (15.0 ft) of glacial till. MP #4 was cased with 10.16 cm (4.00 in) PVC, the lowest portion of which was slotted. MP #5, also drilled in 1974, was used only as a source of historical upgradient ground-water quality data. It was completed in glacial till to a depth of 6.1 m (20.0 ft) and was cased with 10.16 cm (4.00 in) PVC, a section of which was slotted to permit water infiltration.

MP #1, the water supply well, is located on the floodplain south of the millfill. When drilled in 1974, it encountered variously-textured glacial outwash to its completed depth of 13.4 m (44.0 ft). The well was cased to the bottom with 15.24 cm (6.00 in) steel casing, the lowermost section of which was slotted. It provided samples of downgradient ground water.

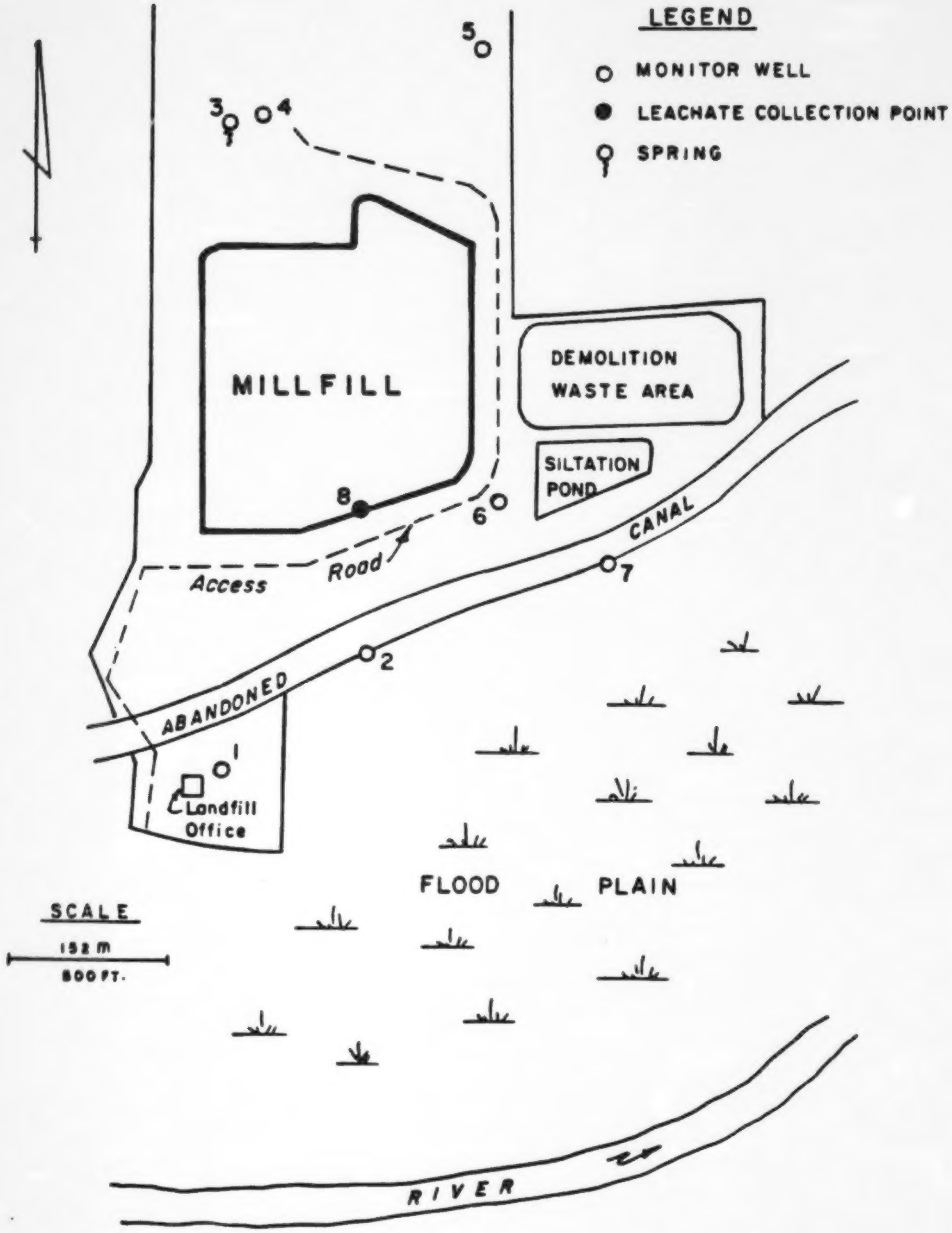

LEGEND
○ MONITOR WELL
● LEACHATE COLLECTION POINT
SPRING
1
2
3
4
5
6
7
8
MILLFILL
DEMOLITION WASTE AREA
SILTATION POND
Access Road
ABANDONED CANAL
Landfill Office
FLOOD PLAIN
RIVER
SCALE
152 m
500 FT.

Figure 28. Location of monitoring points at the millfill site.

TABLE 9. MONITOR WELL CONSTRUCTION DETAILS - MILLFILL[a]

MP #	Well depth	Total[b] casing	Type casing	Section slotted	Elevation[c] Top of casing	Reference[d]	Surface[e] elevation
1	13.4 (44.0)	13.4 (44.1)	15.24 cm (6.00 in.) Steel	----[f]	247.33 (811.13)	0.04 (0.13)	247.19 (811.00)
2	----	----	15.24 cm (6.00 in.) Steel	----	247.08 (810.63)	0.19 (0.63)	246.89 (810.00)
4	3.7 (12.0)	3.7 (12.2)	10.16 cm (4.00 in.) PVC	----	265.85 (872.20)	0.06 (0.20)	265.79 (872.00)
5	6.1 (20.0)	6.1 (20.0)	10.16 cm (4.00 in.) PVC	----	267.46 (877.50)	0.00 (0.00)	267.46 (877.50)
6	8.4 (27.7)	9.1 (30.0)	10.16 cm (4.00 in.) PVC	8.4- 5.4 (27.7-17.7)	254.29 (834.30)	0.70 (2.30)	253.59 (832.00)
7	7.5 (24.5)	8.3 (27.2)	10.16 cm (4.00 in.) PVC	7.5- 4.4 (24.5-14.5)	248.62 (815.70)	0.82 (2.70)	247.80 (813.00)

[a] Measurements in meters (feet) unless otherwise indicated.
[b] Total casing is equal to the casing in the ground plus casing above ground (Reference).
[c] All elevations relative to mean sea level.
[d] Reference above ground surface from which water level measurements are taken.
[e] Surface elevation estimated from USGS topographic map.
[f] Dashes indicate information not available.

MP #2, an observation well drilled in 1974, was located approximately 130 m (425 ft) south of the millfill to monitor ground-water quality directly downgradient from the oldest section of the millfill. No logs were available for this well.

MP #6 was drilled in 1978 on the eastern end of a ridge composed of glacial outwash. It was located approximately 46 m (150 ft) southeast of the millfill to monitor downgradient ground-water quality and was drilled to a depth of 10.7 m (35.0 ft) in glacial outwash. Because of caving, it was cased to 8.4 m (27.7 ft) with 10.16 cm (4.00 in) PVC slotted for the lowermost 3.0 m (10.0 ft). MP #7, also drilled in 1978, was located approximately 168 m (550 ft) southeast and downgradient of the millfill and immediately downgradient of the siltation pond. It was drilled to a depth of 9.1 m (30.0 ft) in fine to medium gravels with minor amounts of silt and clay and, because of caving, was cased to 7.5 m (24.5 ft) with 10.16 cm (4.00 in) PVC slotted for the lowermost 3.0 m (10.0 ft).

Particle Size Analyses

Three samples obtained during the drilling of MP #6 and MP #7 were analyzed for particle size distribution to better determine the attenuation characteristics of the geologic material (see Appendix B and Table 10). The samples are glacial outwash. The one from MP #6 is sandy; those from MP #7 are gravelly and become coarser with increasing depth. None of these samples contains large enough amounts of clay to allow significant ion exchange with the leachate to occur.

Hydrogeology of the Millfill Site

The millfill is located on the side slope of a major river valley in an area of comparatively high relief. Glacial sediments in which the landfill is developed exhibit a steep southerly slope towards the river. Drainage is provided by small streams; the drainage network in the area is well-developed and has a comparatively steep grade, and the river to which the small streams drain has considerable stream flow. Ground water at the site moves to the southeast toward the river. The glacial outwash underlying the river forms an aquifer which discharges into the river. The uplands, mantled with a relatively impermeable till, serve as the local recharge area.

Hydrologic data for the area is sparse. The area immediately to the north of the millfill, however, has been studied in more detail and, since the climate of the area is comparable, the results of those hydrologic studies have been used to develop a water budget for the site.

TABLE 10. PERCENTAGE OF SEPARATES BY WEIGHT FOR THE GEOLOGIC MATERIALS AT THE MILLFILL.[a]

Sample description	% Clay	% Silt	% Sand	% Coarse fragments
MP #6 Outwash 3.0 - 10.7 m (10.0 - 35.0 ft)	6	21	60	13
MP #7 Outwash 3.0 - 6.1 m (10.0 - 20.0 ft)	4	11	30	55
MP #7 Outwash 7.6 - 9.1 m (25.0 - 30.0 ft)	3	6	11	80

---

[a] Size limits for the soil separates are based on the U. S. Department of Agriculture system. The diameter range for separates is:

Clay, less than 0.002 mm
Silt, 0.002 - 0.05 mm
Sand, 0.05 - 2.0 mm
Coarse Fragments, greater than 2.0 mm

The water budget developed for the millfill area is based on long-term regional data modified slightly to fit conditions at the site. The budget indicates that, of the 83.69 cm (32.95 in) of precipitation (PPT) which falls on the area, 61 percent is lost to evapotranspiration (ET), 13 percent runs off as surface water (SW) and 26 percent recharges the ground water (GW). The budget, in the form of an equation, is:

$$\begin{array}{ccccccc} \text{PPT} & = & \text{ET} & + & \text{SW} & + & \text{GW} \\ 83.69\ \text{cm} & = & 1.05\ \text{cm} & + & 10.88\ \text{cm} & + & 21.76\ \text{cm} \\ (32.95\ \text{in}) & = & (20.10\ \text{in}) & + & (4.28\ \text{in}) & + & (8.57\ \text{in}) \end{array}$$

Hydrogeologic conditions at the millfill, although not identical to those of the region, are similar. The differences between the landfill itself and the region surrounding it are the permeability of the cover material used at the millfill and the natural vegetation of the region contrasted with the absence of vegetation at the landfill. However, since care has been taken to cover the landfill with impermeable material and to compact it, evapotranspiration losses because of limited vegetation on the landfill surface are minimized. Therefore, the budget presented here is appropriate given the limited data available regarding the millfill site.

Leachate generation at the millfill can be estimated using the water budget and the area of the millfill base. Multiplying the 21.76 cm (8.57 in) of recharge by the 7-ha (18-ac) base yields 15,232 m^3 (12.86 ac-ft) per year of potential leachate generation which will tend to move with the ground water to the south and discharge in the vicinity of the river.

Figure 29 shows a cross section of the millfill taken along line AA' (see Figure 30) passing roughly northwest to southeast through MP #4, #8, and #2. The millfill was constructed on a thin base of compacted glacial sediments obtained from the northern portion of the site. It overlies approximately 15 m (50 ft) of intertonguing outwash and till.

The water table generally follows the contour of the land. Depth to the water table around the millfill ranges from 1.34 to 6.62 m (4.40-21.70 ft), see Appendix C. Average seasonal fluctuations in the water table range from 0.18 to 1.38 m (0.60-4.52 ft). Figure 31 shows the approximate water table configuration in the study area based on water table elevations from four points. Precipitation percolates down to the water table where it enters the ground-water flow system moving to the south and ultimately discharging into the river. After leaving the millfill, leachate perco-

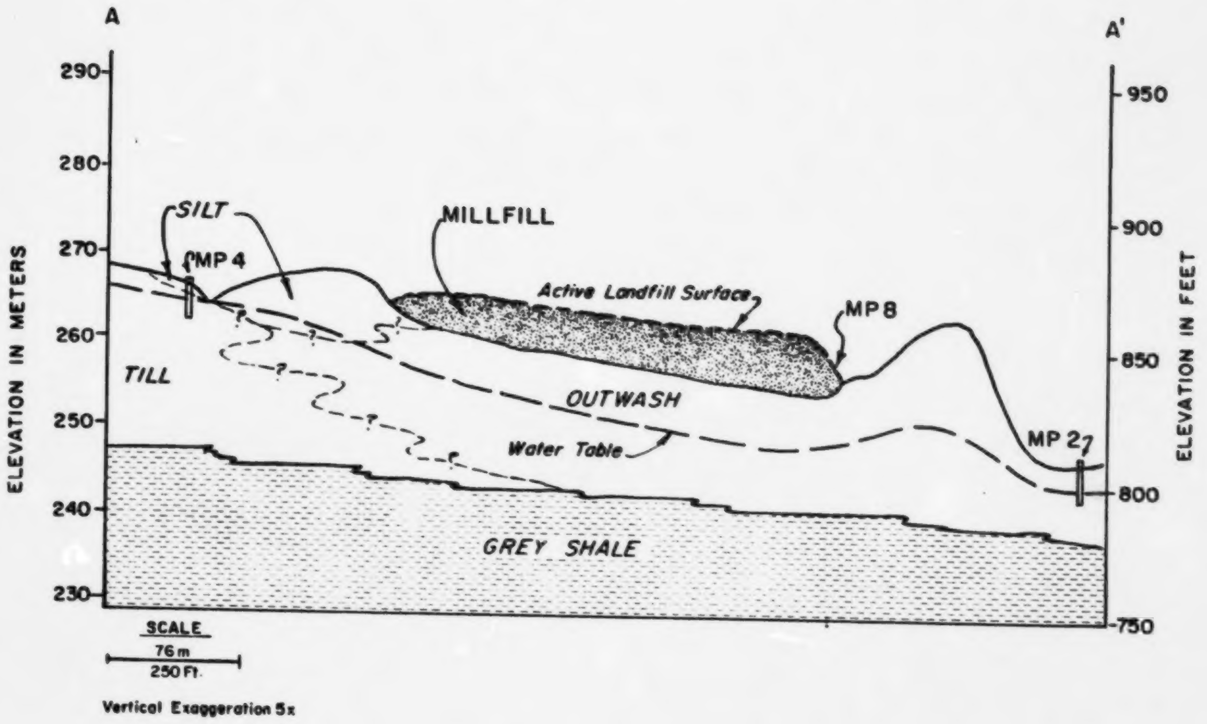

A
A'
290
280
270
260
250
240
230
ELEVATION IN METERS
950
900
850
800
750
ELEVATION IN FEET
SILT
MP 4
MILLFILL
Active Landfill Surface
MP 8
MP 2
TILL
OUTWASH
Water Table
GREY SHALE
SCALE
76 m
250 Ft.
Vertical Exaggeration 5x

Figure 29. Cross section of the millfill site.

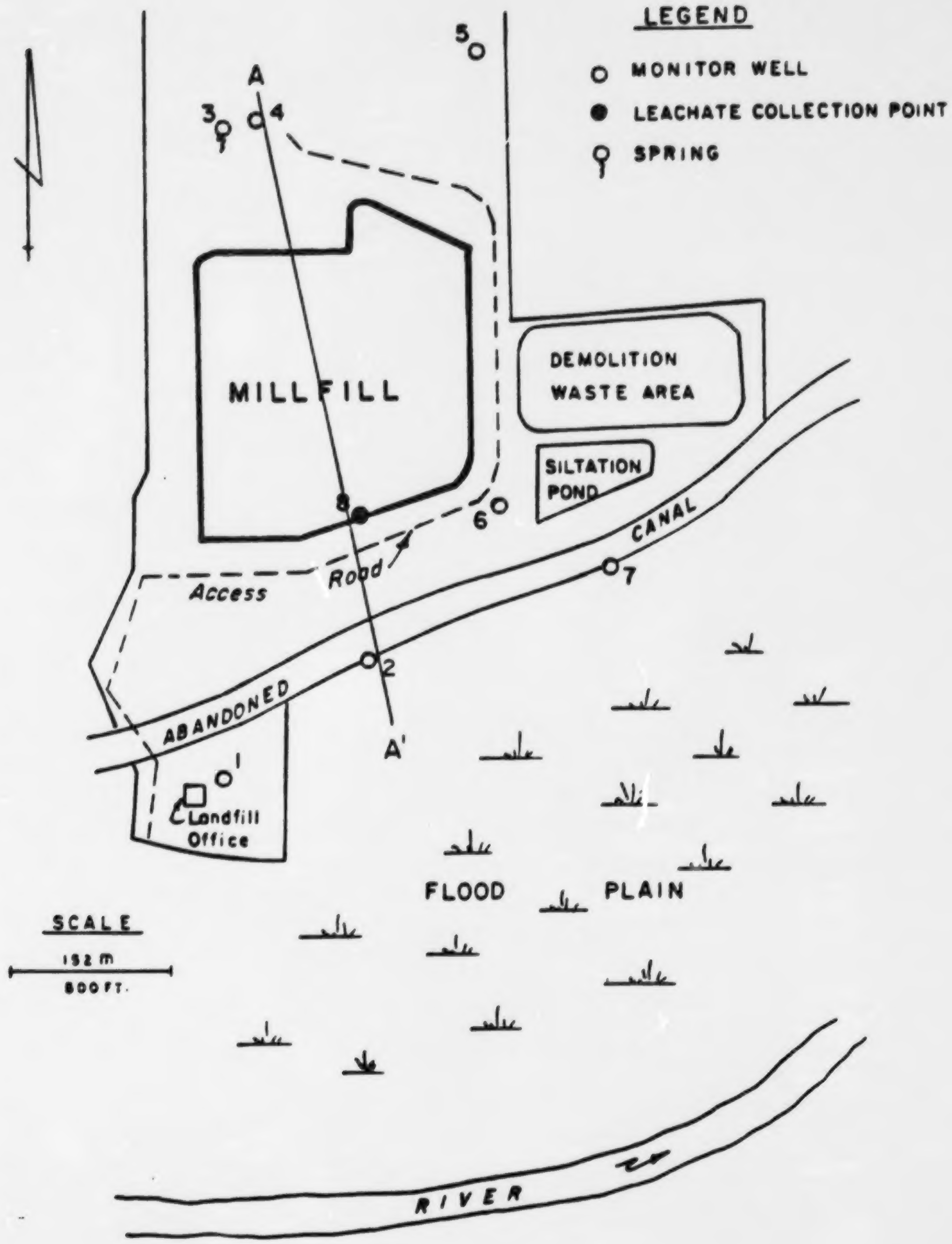

LEGEND
○ MONITOR WELL
● LEACHATE COLLECTION POINT
SPRING
A
A'
1
2
3
4
5
6
7
8
MILLFILL
DEMOLITION WASTE AREA
SILTATION POND
Access Road
ABANDONED CANAL
Landfill Office
FLOOD PLAIN
RIVER
SCALE
152 m
500 FT.

Figure 30. Map showing the location of the line of cross section, AA'.

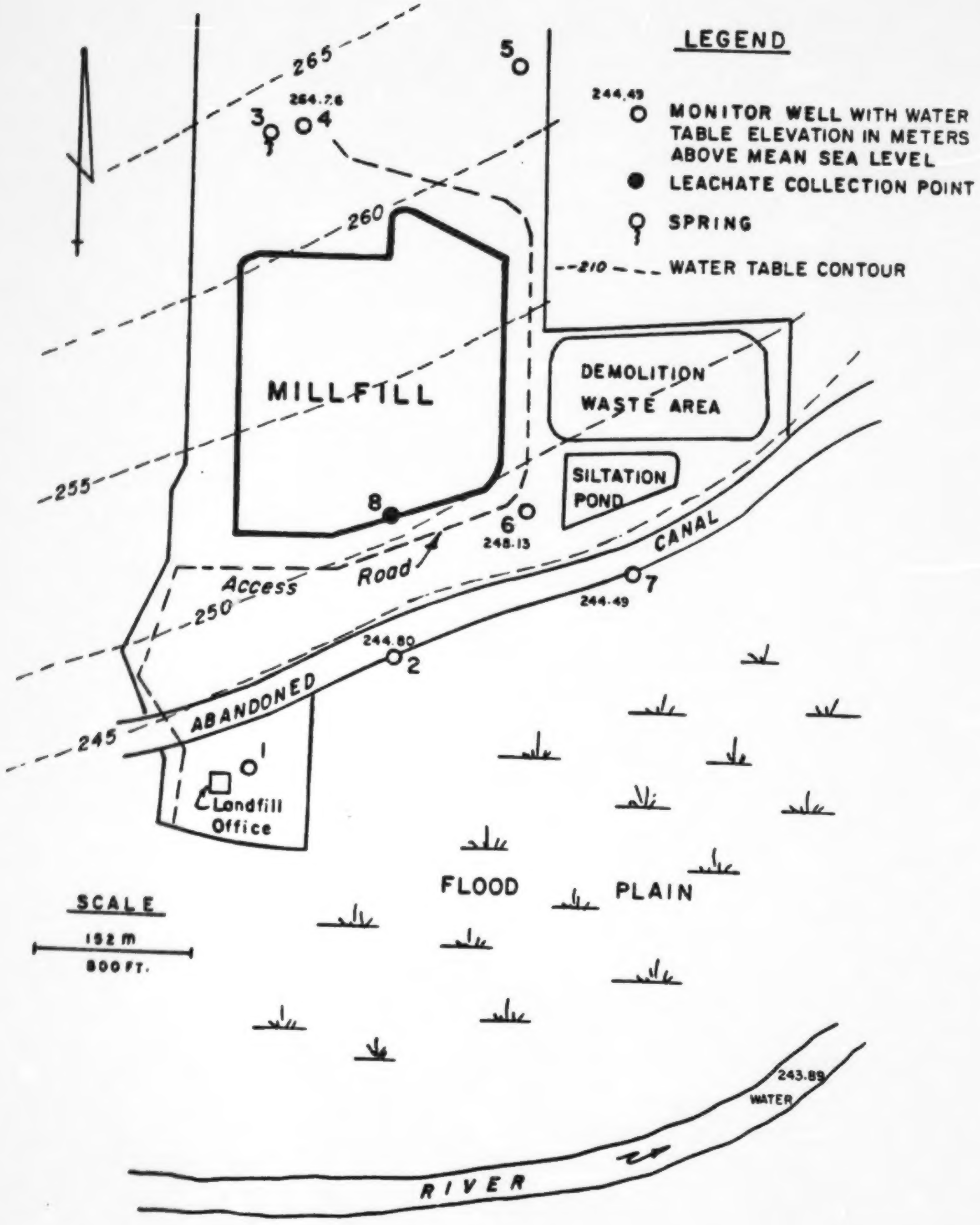

LEGEND
244.49
MONITOR WELL WITH WATER TABLE ELEVATION IN METERS ABOVE MEAN SEA LEVEL
LEACHATE COLLECTION POINT
SPRING
210
WATER TABLE CONTOUR
265
260
255
250
245
5
3
4
264.76
MILLFILL
DEMOLITION WASTE AREA
SILTATION POND
8
6
248.13
Access Road
CANAL
7
244.49
244.80
2
ABANDONED
1
Landfill Office
SCALE
152 m
500 FT.
FLOOD
PLAIN
243.89
WATER
RIVER

Figure 31. Map of the water table at the millfill site.

lates down to the shallow outwash aquifer and is diluted and dispersed as it is transported along the ground-water flow path.

Water Chemistry at the Millfill Site

Bar graphs of the mean concentrations for alkalinity, acidity, TDS, TKN, COD, and TOC were constructed for all the monitoring points (see Figures 32, 33, and 34, Appendix E and Section 2). The background water quality is represented by MP #4 and MP #3 which have mean values for alkalinity of 74.3 mg/l and 62.3 mg/l, respectively (see Figure 32). The leachate (MP #8, 9,450 mg/l) has a mean value for alkalinity considerably higher than either MP #3 or #4. All four of the downgradient wells (MP #1, #2, #6, and #7) show mean values for alkalinity higher than those for either MP #3 or #4. Ranking these sampling points in order of decreasing concentrations, MP #2 has the highest concentration of alkalinity (mean value of 393.8 mg/l), MP #7 exhibits the next highest mean value (198.0 mg/l) and MP #1 and MP #6 show similar mean concentration values of 178.3 mg/l and 170.5 mg/l, respectively. While all of these sampling points have alkalinity values higher than those observed in the background well, they are more than an order of magnitude lower than those of the leachate.

The mean concentration values for acidity are displayed in Figure 32 which shows patterns that are similar to those seen in the alkalinity values. The background well (MP #4) and the spring (MP #3) demonstrated the least negative mean values for acidity, showing -110 mg/l and -64 mg/l, respectively. The leachate (MP #8) gave the most negative mean value for this parameter with -4,360 mg/l of acidity. MP #2 (-187 mg/l) had the most negative mean value among the downgradient wells. MP #7 yielded the next most negative value showing -210 mg/l of acidity. MP #1 (-188 mg/l) and MP #6 (-180 mg/l) presented the two least negative mean values for acidity.

The bar graph of the mean values for TDS (see Figure 33) demonstrates a configuration similar to that seen in the bar graphs for alkalinity and acidity. MP #8 (leachate) has the highest mean concentration of TDS with a value of 19,500 mg/l. This value is nearly 2 orders of magnitude higher than the mean concentration value for TDS found at any of the other monitoring points. MP #3 (112 mg/l) and MP #4 (160 mg/l), the background monitoring points, have the lowest mean concentration values of TDS. MP #2 (396 mg/l) shows a mean concentration which is the highest among the downgradient wells; MP #7 (281 mg/l) has the next highest TDS concentration. MP #1 (255 mg/l) and MP #6 (250 mg/l) have relatively equivalent mean values.

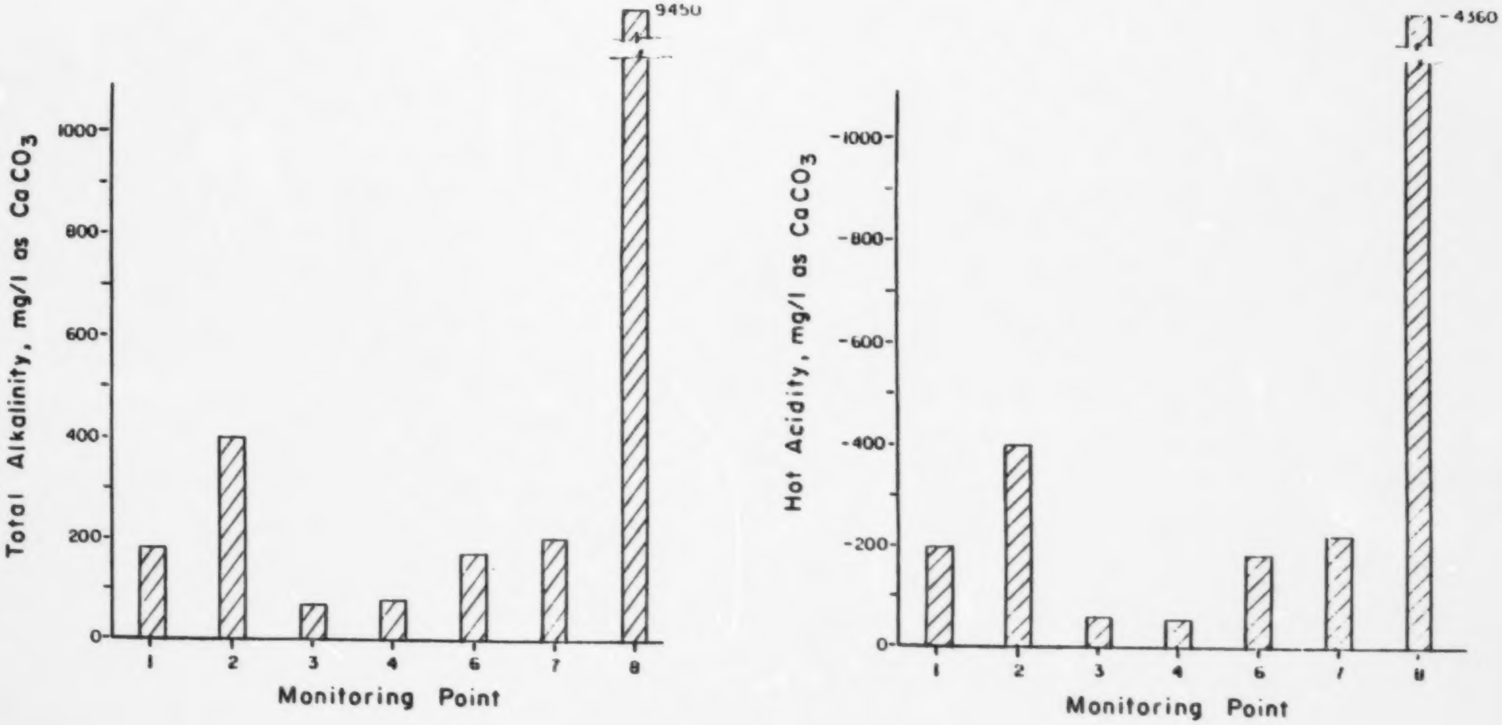


Figure 32. Bar graphs for alkalinity and acidity at the millfill site.

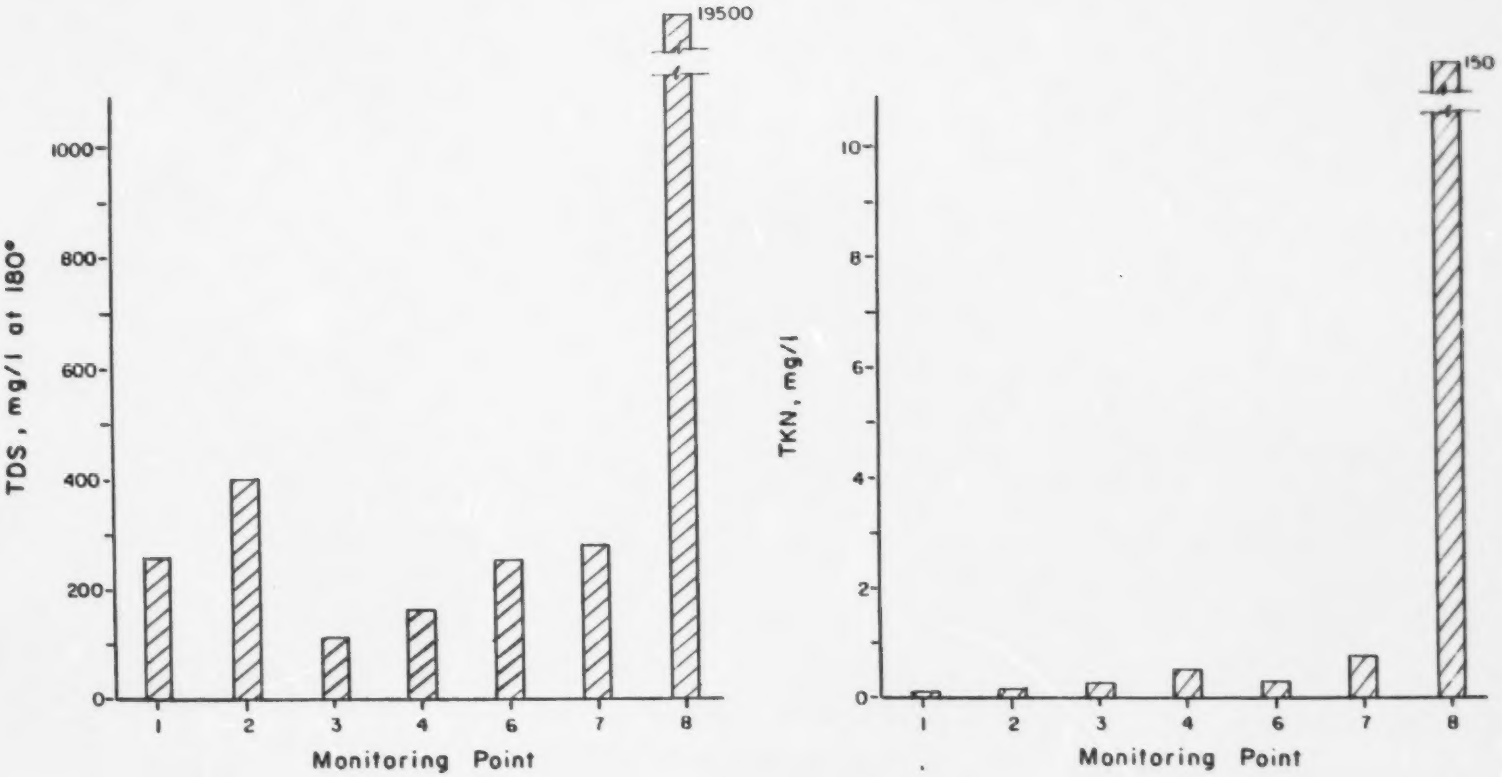


Figure 33. Bar graphs for TDS and TKN at the millfill site.

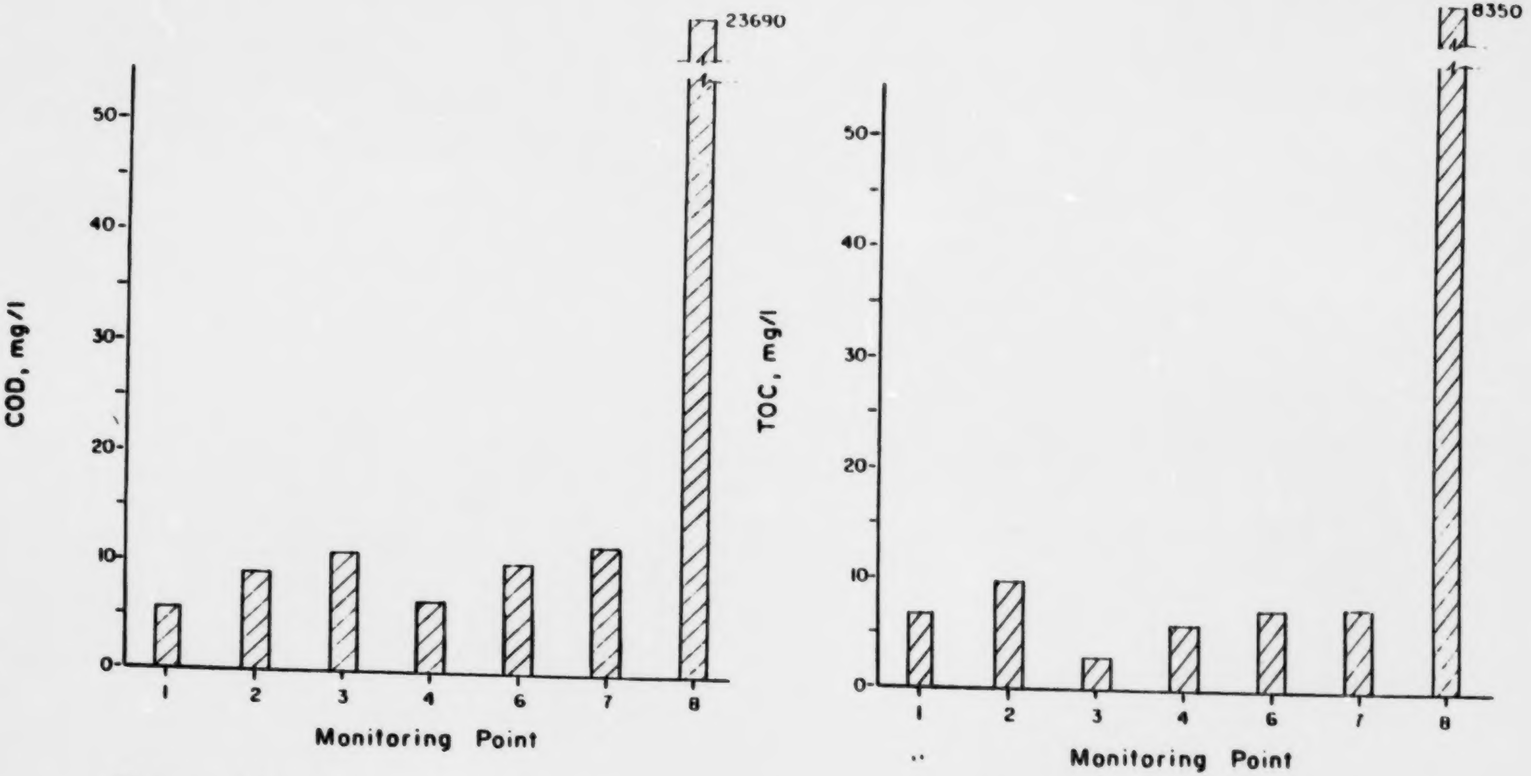


Figure 34. Bar graphs for COD and TOC at the millfill site.

MP #8 shows a significant concentration of TKN and has a mean value (150 mg/l) that is more than 2 orders of magnitude higher than those of the other monitoring points (see Figure 33). The spring (MP #3), the background well (MP #4), and all of the downgradient wells (MP #1, #2, #6, and #7) have mean concentration values for TKN that are less than 1.00 mg/l. The difference between the monitoring point with the highest mean concentration of TKN (MP #7) and the one with the lowest mean concentration (MP #1) is only 0.64 mg/l. Thus, given the low concentration levels of this parameter and the small magnitude of the difference among the monitoring points, it would be unwise to attempt to identify patterns within this data.

The mean values for COD are displayed in Figure 34. As with the previous histograms, the leachate (MP #8) showed the highest mean value (23,690 mg/l) among the monitoring points. This value exceeds those found at the other monitoring points by more than 3 orders of magnitude. Downgradient wells MP #2 (8.70 mg/l), MP #6 (10.00 mg/l), and MP #7 (11.73 mg/l) exhibited mean concentrations for COD that were higher than that of the background well (MP #4, 6.32 mg/l). Although the mean COD values for these three downgradient wells were higher than that seen in the background well (MP #4), the values are all relatively low. The remaining downgradient point (MP #1, 5.43 mg/l) has a mean value for COD lower than the background value (6.23 mg/l).

The mean concentrations for TOC are displayed in Figure 34. The leachate (MP #8) has a mean concentration value of 8,350 mg/l and is more than 2 orders of magnitude higher than the mean values for all of the other monitoring points. Both background monitoring points (MP #3, 2.7 mg/l and MP #4, 5.8 mg/l) showed low values for TOC. All downgradient wells showed mean concentrations of TOC higher than either MP #3 or #4. MP #2 (9.4 mg/l) has the highest mean TOC concentration among the downgradient wells. MP #6 (7.1 mg/l) and MP #7 (7.4 mg/l) show roughly equivalent mean concentrations. MP #1 (6.4 mg/l) has a slightly lower mean concentration value. As was the case with the COD values, all of these values for the downgradient wells are low considering the strength of the leachate.

In summary, the bar graphs show the leachate (MP #8) to be of considerable strength. They also show that it has affected all of the downgradient wells to varying degrees. MP #2 demonstrated the highest amount of impact. This may be a function of the position of the well downgradient of the oldest portion of the millfill where the refuse was buried in an abandoned gravel pit. The proximity of the refuse to the water table results in a greater potential for the production of leachate and contamination of ground water. The age of the material is reflected in a relatively low mean value for COD. The fact that the levels of the water quality indicators are considerably lower at MP #2 than at MP #8 shows that the leachate has undergone attenuation, degradation, and dilution.

The bar graphs for MP #7 show that this well also is contaminated. There appears to be two sources of contamination at this monitoring point; the leachate from the millfill and leachate from side seeps that is carried along with runoff via ditches which empty into the siltation pond. Leachate contained in the unlined siltation pond enters the ground-water system and affects water quality at MP #7. This observation of two sources is supported by the fact that the parameter values for MP #7 are consistently higher than those at MP #6.

The histograms for MP #6 show that the millfill has an impact on this well but to a lesser degree than either MP #2 or #7. This phenomenon is a reflection of the location of MP #6 downgradient from the newer portion of the millfill. This leachate appears to be of weaker strength. The bar graphs of TOC and COD show MP #6 to have mean parameter values similar to those at MP #7. These elevated mean values are characteristic of leachate produced by the newer refuse in the millfill.

MP #1 exhibited the lowest amount of impact among the downgradient wells. Although alkalinity, acidity, and TDS at this monitoring point show evidence of minimal contamination, COD and TOC do not. The higher mean values for the first three parameters are explained by the fact that these undergo only a minor amount of attenuation along the flow path due to the porosity of the sands and gravels beneath and surrounding the site. However, the relatively greater distance to MP #1 affords time necessary to degrade the carbonaceous material. The low degree of the impact of the millfill on MP #1 may be best appreciated when it is noted that the water from this well is potable.

In order to further illustrate the effect of the millfill on the quality of the ground water in the area, Stiff diagrams were constructed (see Figure 35). The diagram for MP #8 (undiluted leachate) has a distinctive shape and shows elevated concentrations of all the ionic species considered: sodium, iron, manganese, zinc, chloride, sulfate, nitrate, and phosphate.

The shapes of the diagrams for MP #1 and MP #7 are more similar to that for MP #3 (the spring) than that for any other monitoring point. The Stiff diagram for MP #6 is

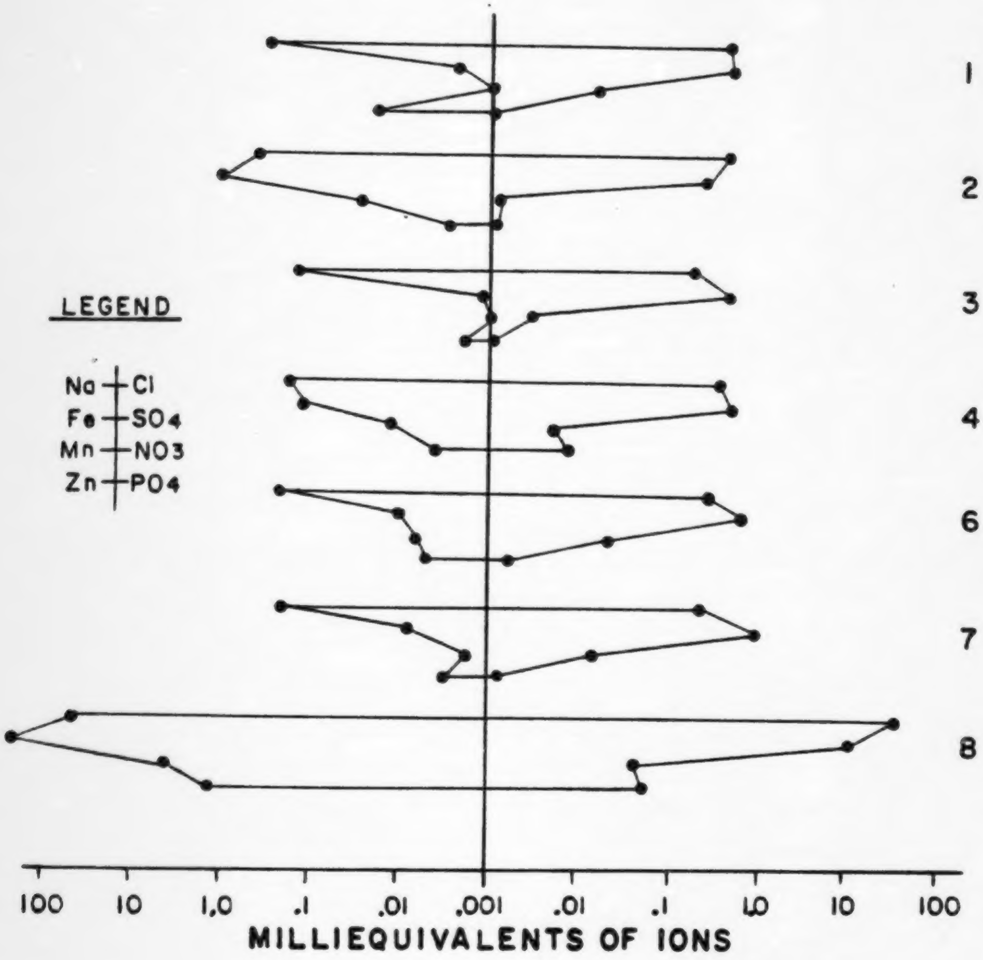


Figure 35. Modified stiff diagrams showing averaged results of chemical analyses at the millfill site.

somewhat like that seen for MP #7 but shows higher concentrations of all ions except sulfate.

The shape of the diagram for MP #2 resembles that of MP #8, indicating similar ionic composition. This supports the suggestion that two types of leachate are being produced from the older and newer portions of the millfill. The width of the diagram for MP #2, however, shows that the leachate contacting this monitoring point has been diluted. The relatively high concentrations of sodium indicate a lack of attenuation between MP #2 and the millfill.

Overall, the Stiff diagrams demonstrate that downgradient wells, MP #2, #6, and #7 have all been impacted by the presence of the millfill but to varying degrees. The shape of the diagram for MP #2 indicates that this well is the most heavily impacted among the downgradient wells.

The Stiff diagrams support the earlier suggestion that the siltation pond is an additional source of contamination at MP #7. The different shape of the diagram for MP #7 as compared to MP #6, suggests a different type of leachate. MP #6 exhibits higher concentrations of all ionic species except sulfate which is higher at MP #7.

MP #1 demonstrated the least degree of impact among the downgradient wells. Overall, it exhibited the lowest concentrations of ionic species except for zinc and chloride.

To differentiate between oxidizing and reducing environments, nitrogen ratios were calculated and are displayed on Figure 36. A large ratio value of 53.6 for MP #8 demonstrates that the leachate is under reducing conditions.

Among the downgradient wells, MP #2 had the highest ratio value (2.09) indicating a somewhat reducing environment. MP #7 (0.87) gave evidence of a more oxidizing environment than MP #2. The great difference between the ratio value for MP #8 (the leachate) and MP #2 shows that the leachate has been diluted by ground water and that some degradation of the leachate occurs before it contacts MP #2.

MP #6 exhibits a ratio of 0.26 which indicates that a more oxidizing environment exists here than at MP #7. The lower ratio for MP #6 compared to MP #2 is a reflection of the proximity of MP #6 to relatively newer refuse (compared to MP #2 the older refuse in the southwest portion of the millfill).

MP #1 (0.12) exhibited the lowest nitrogen ratio value among all the monitoring points. Its low value reflects both its distance from the millfill and the fact that MP #1

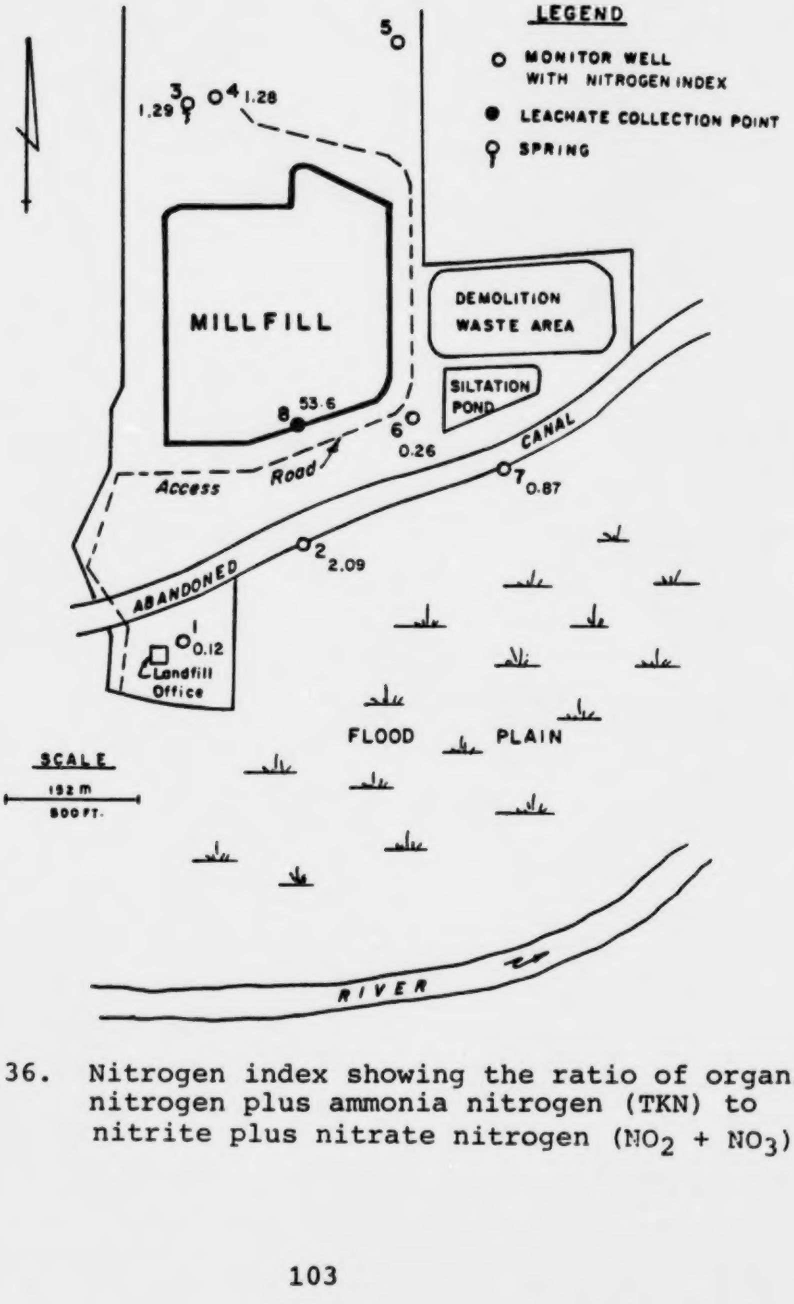

LEGEND
○ MONITOR WELL WITH NITROGEN INDEX
● LEACHATE COLLECTION POINT
SPRING
1 0.12
2 2.09
3 1.29
4 1.28
5
6 0.26
7 0.87
8 53.6
MILLFILL
DEMOLITION WASTE AREA
SILTATION POND
Access Road
ABANDONED CANAL
Landfill Office
FLOOD PLAIN
SCALE
152 m
500 FT.
RIVER

Figure 36. Nitrogen index showing the ratio of organic nitrogen plus ammonia nitrogen (TKN) to nitrite plus nitrate nitrogen ($NO_2 + NO_3$).

is downgradient of the oldest portion of the millfill. Since MP #1 is the farthest downgradient monitoring point, the leachate becomes more diluted prior to reaching it. The material producing the leachate is older and there has been more time for it to have undergone degradation.

Unfortunately, the historical data for the millfill is limited (see Appendix D). However, a sufficient number of analytical results exist to allow the identification of trends (or their absence) in alkalinity, specific conductance, and total solids for two of the downgradient wells (MP #1 and #2), the spring (MP #3) and the background well (MP #4).

At MP #2 the peak values for alkalinity, specific conductance, and total solids are greater than those seen at MP #1. The fact that the parameter values for MP #2 are higher is due to the proximity of the well to the millfill.

The data for MP #3 (the spring) and MP #4 (background) exhibits a considerable amount of variability and no definite trends through time could be identified. The data does show, however, that the parameter values for the downgradient wells (MP #1 and #2) are generally higher than those seen in the spring or the background well.

In summary, the data demonstrates that MP #2 and #7 are the most contaminated of the downgradient wells. The contamination source for MP #2 is the strong leachate produced directly by the older portion of the millfill while the leachate which has been diluted by surface runoff water from the siltation pond and the newer leachate is the contamination source for MP #7.

The data also shows that MP #1 has the least amount of contamination among the downgradient wells. The impact on the well is minor due to the fact that contamination is localized; MP #1 is farthest from the millfill among the downgradient wells.

MP #6 exhibits an intermediate amount of contamination relative to the other monitoring points. This is attributable to the fact that MP #6 is impacted by one source of contamination, the weaker leachate from the newer portion of the millfill.

STRIP MINE LANDFILL

The requirements for energy in the United States have encouraged the increasing use of strip mine landfilling. With the advent of stricter requirements concerning the reclamation of strip mines, it has seemed advantageous to use solid waste as the fill material necessary to regrade abandoned strip pits. In addition to the obvious cost advantage of using these ready-made depressions, strip mines are often located in sparsely populated areas where the presence of a landfill would have relatively less social impact.

Topographic Position

The strip mine landfill lies on the border of the Allegheny High Plateau and Pittsburgh sections of the Appalachian Plateau physiographic province. The site was not directly affected by glaciation and only a thin mantle of soil covers the nearly horizontal bedrock. The bedrock has been dissected by numerous streams and rivers creating fairly steep, rounded mountains separated by small valleys. The landfill is located on a mountain side which slopes steeply into a small stream valley (see Figure 37). Local relief at the landfill is on the order of 61 m (200 ft).

Drainage for the area is well-integrated with small mountain tributaries feeding larger trunk streams and creeks. A number of local drainage divides are present in the area creating an irregular directional flow pattern. A small spring-fed stream originates approximately 518 m (1700 ft) east of the landfill and flows southwesterly through the small valley at the base of the strip-mined mountain joining with a northwesterly flowing creek approximately 1.6 km (1 mile) southwest of the site. A small spring-fed pond is located below spoil banks at the eastern slope of the strip cut.

The area is heavily forested, although numerous clearings are present as a result of mining and clear-cutting operations. There are a few small farms in the area. The completed portions of the landfill have been revegetated with native grasses.

Climate

The climate at the strip mine landfill is humid continental, characterized by relatively dry, cold winters and warm to hot, wet summers.

Based on data compiled by the U.S. Weather Bureau at a nearby weather station, precipitation for the one-year study period was 111.02 cm (43.71 in). Although normal precipitation data for this particular station was unavailable, regional data indicates a normal yearly total of approximately 104.1 cm (41.0 in), see Figure 38 and Table 11.

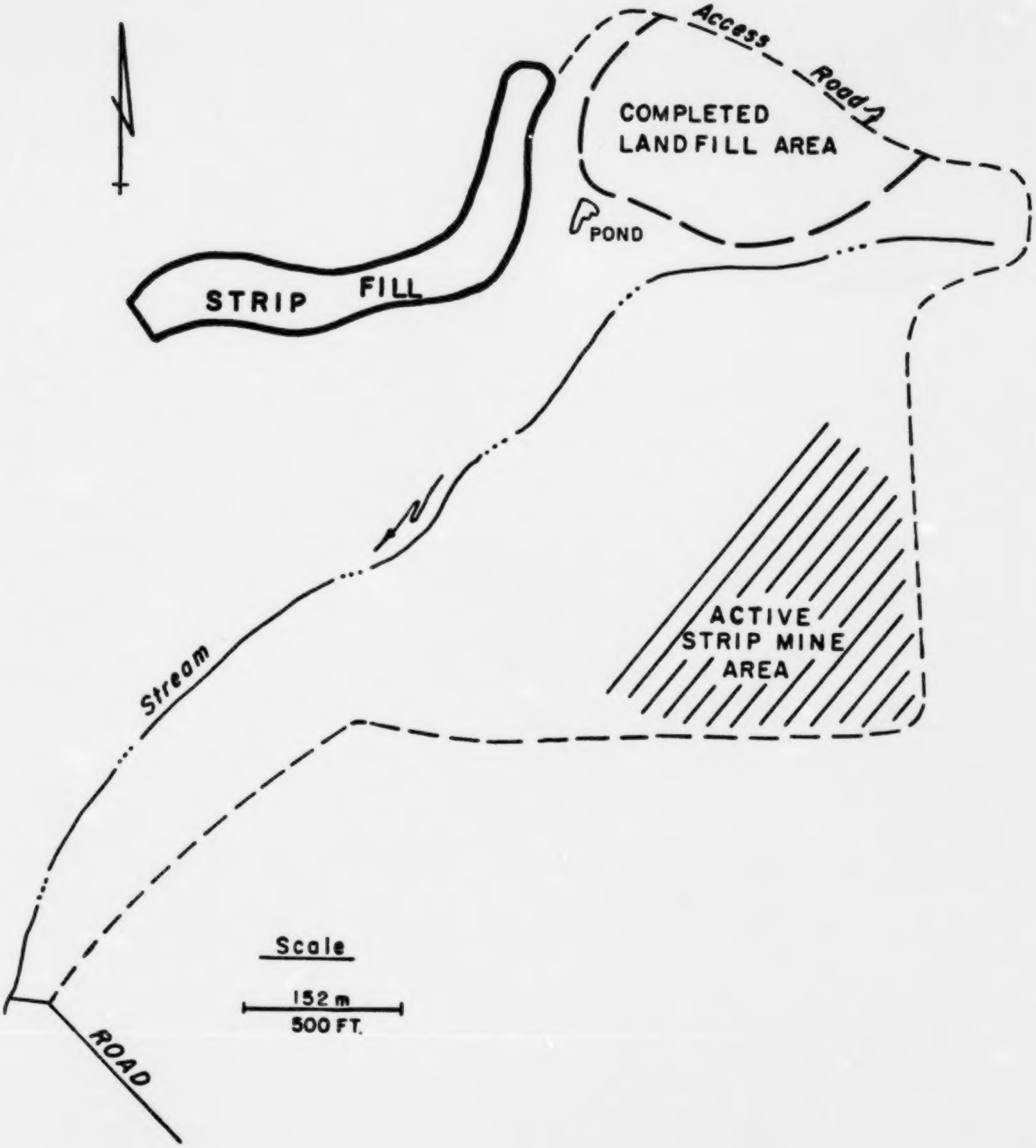

Access Road
COMPLETED LANDFILL AREA
POND
STRIP FILL
ACTIVE STRIP MINE AREA
Stream
Scale
152 m
500 FT.
ROAD

Figure 37. Map of the strip mine landfill site.

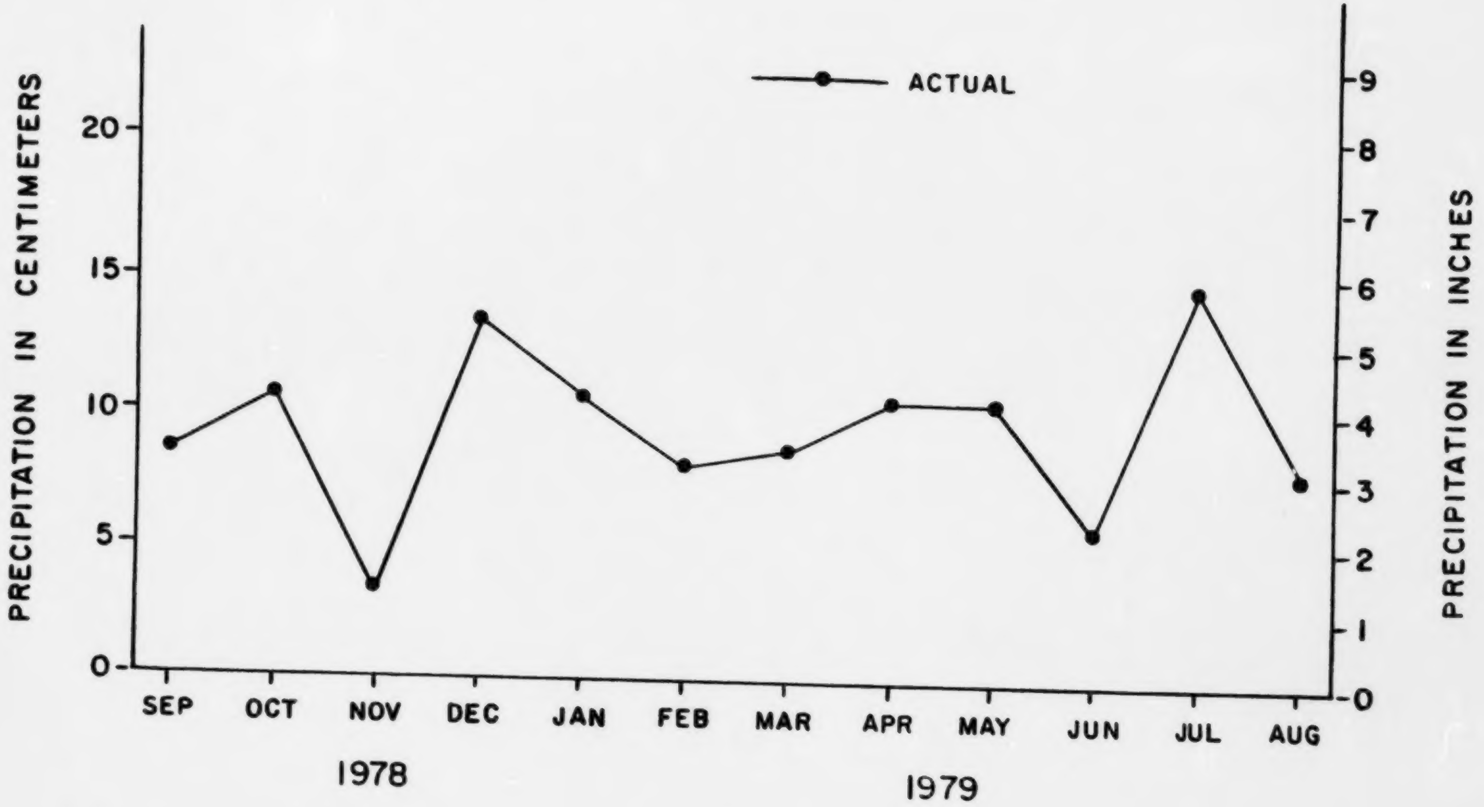


Figure 38. Graph of precipitation at the strip mine landfill.

TABLE 11. MONTHLY PRECIPITATION DATA[a]
STRIP MINE LANDFILL

Date	Actual
9/78	8.43 (3.32)
10/78	10.31 (4.06)
11/78	3.33 (1.31)
12/78	13.21 (5.20)
1/79	10.46 (4.12)
2/79	8.10 (3.19)
3/79	8.74 (3.44)
4/79	10.39 (4.09)
5/79	10.21 (4.02)
6/79	5.61 (2.21)
7/79	14.55 (5.73)
8/79	7.67 (3.02)
TOTAL	111.02 (43.71)

[a] Measurements in cm (in)

The wettest months during the study period were December 1978 and July 1979 with 13.21 cm (5.20 in) and 14.55 cm (5.73 in) respectively. The driest months recorded during the study period were November 1978 with 3.33 cm (1.31 in) of precipitation and June 1979 with 5.61 cm (2.21 in). Snowfall accounts for significant amounts of precipitation during the winter months.

The average temperature for the study period was 8.0 C (46.4 F). The coldest month was February with an average temperature of -8.7 C (16.3 F) and the warmest month was July, averaging 20.7 C (69.2 F).

Geology

The strip mine landfill is located in the Appalachian Plateau physiographic province. Bedrock in the area is covered by a thin mantle of soil. Regionally, bedrock is mapped as the Allegheny and Conemaugh Groups of Pennsylvanian age which are highly variable, cyclic deposits characteristic of the Pennsylvanian cyclothems (see Figure 39). Landfilling operations were established in a pit created during strip mining of the Upper Freeport Coal seam. During the process, the overlying Glenshaw Formation was removed to expose the coal.

The Allegheny Group underlying the landfill is composed of interbedded sandstones, siltstones, shales, marine and fresh-water limestones, coal seams and clays. Individual members of the group vary widely both in lateral and vertical extent although the total thickness of the Allegheny Group (107 m, 350 ft) is relatively uniform.

The uppermost formation of the Allegheny Group is the Freeport Formation which contains two mineable coal seams (Upper and Lower Freeport Coals), distinctive in that they are underlain by thin fresh-water limestones. Between these coal seams is an interval of 6 to 18 m (20-60 ft) of shale and minor coal seams. However, in some places the shale is absent and is replaced by the Butler Member, a massive, coarse-grained sandstone.

The base of the Freeport Formation consists of 12 to 15 m (40-50 ft) of shale, but in places the Freeport Sandstone becomes prominent. The lithologic character varies from a fine-grained, flaggy rock to a coarse-grained, conglomeratic sandstone.

Three formations lie beneath the Freeport and exhibit character similar to it except for the Vanport Limestone which is a fossiliferous marine limestone. The Vanport

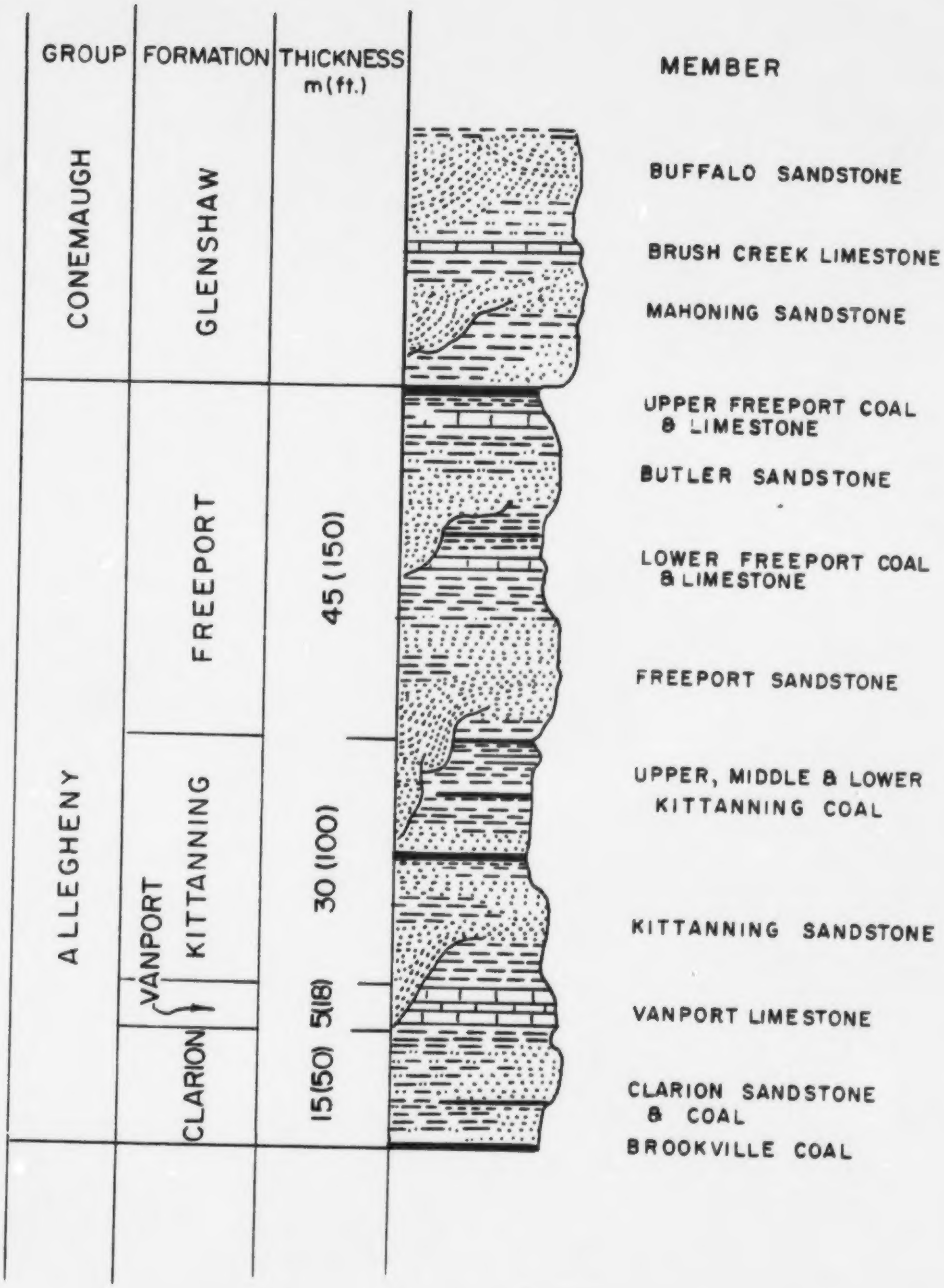

GROUP
FORMATION
THICKNESS m(ft.)
MEMBER
CONEMAUGH
GLENSHAW
ALLEGHENY
FREEPORT
KITTANNING
VANPORT
CLARION
45 (150)
30 (100)
5(18)
15(50)
BUFFALO SANDSTONE
BRUSH CREEK LIMESTONE
MAHONING SANDSTONE
UPPER FREEPORT COAL & LIMESTONE
BUTLER SANDSTONE
LOWER FREEPORT COAL & LIMESTONE
FREEPORT SANDSTONE
UPPER, MIDDLE & LOWER KITTANNING COAL
KITTANNING SANDSTONE
VANPORT LIMESTONE
CLARION SANDSTONE & COAL
BROOKVILLE COAL

Figure 39. Typical stratigraphic column for Pennsylvanian-age coal measures.[1]

Limestone has an average thickness of about 3 m (10 ft) and usually contains about 90 percent calcium carbonate.

The Conemaugh Group conformably overlies the Allegheny; however, erosion and mining operations have removed all but the lowermost Glenshaw Formation. These deposits are found on the highlands north and west of the landfill site. The Glenshaw is composed mostly of shale, but in places massive sandstone beds are present. The sandstone beds are irregular both in thickness and lithology and are not easily correlated with one another.

Structurally, the landfill is located on the southeast limb of a gently northeast plunging syncline. The northwest dip of the strata is a result of this minor syncline; the regional dip is to the southwest.

Landfill Operations

The strip mine landfill was opened in June 1971 and is in active operation at present (1980). It is estimated to have an operating life of approximately two more years. The landfill serves a population of approximately 28,600 and receives a combination of residential and commercial refuse and some industrial paper refuse from a nearby mill. No process wastes are accepted. The amount of refuse received daily at the landfill has increased steadily from 31 m^3 (40 yd^3) during the first 3 years, 115 m^3 (150 yd^3) during the next 2 years, 231 m^3 (300 yd^3) for 4 years, to 446 m^3 (580 yd^3) since April 1979. Its operating schedule is 10 hr/day, 6 day/wk, 52 wk/yr. By the end of the present study, 105,000 tonnes (116,000 tons) of waste had been landfilled with an approximate volume of 396,300 m^3 (518,380 yd^3). Density of the landfilled refuse is approximately 263 kg/m^3 (450 lbs/yd^3).

The facility is located on a sloping 15-ha (37-ac) site of which only 5.7 ha (14 ac) is filled (see Figure 37). Coal strip mining operations conducted during the mid-1950s left an open cut on the face of the mountain. The coal had been contour-mined on a hillside and mine spoil material had been deposited down slope from the working cut. Upon completion of the mining operation, no land reclamation had been undertaken, leaving a 12-m (40-ft) exposed highwall. The land was subsequently purchased by a private developer who proposed a landfill reclamation operation for the site.

Two areas were landfilled (see Figure 37). One is located in a small hollow below and to the east of the main strip cut. Refuse was deposited in this area over the bank of the hollow and was subsequently covered with locally available spoil materials. Operations ceased in this area after approximately one year at which time landfilling commenced in the main strip cut. The base of the main strip cut was lined with clayey spoil material and inert industrial waste dust. Refuse is delivered by truck.

In order to establish a working landfill face, refuse was deposited at the base of the highwall and a series of 3.7 to 4.6 m (12-15 ft) lifts were constructed sloping away from the highwall. Each lift was compacted with a bulldozer and covered with spoil material. After the first series of lifts had been completed to the top of the highwall and the desired slope had been attained, a working face was established against this completed area. Subsequent lifts of refuse were compacted and covered on this working face creating a series of sloping refuse cells. These cells are constructed to achieve the desired final slope and to provide for lateral growth of the landfill at its base. At the end of the study, the average volume of waste per unit area was 69,957 m^3/ha (37,027 yd^3/ac).

The daily 15 cm (6 in) of cover material consists of weathered mine spoil (clayey decomposed shale fragments). Final cover is 61 cm (24 in) of spoil material which is placed on completed sections and graded to the desired slope and contour. These sections were successfully revegetated with native grasses; the density, however, was somewhat sparse, as is typical of revegetated mine spoil areas. During the study, minor erosion was observed on parts of the completed slope and several leachate seeps also appeared.

Monitoring Network

The monitoring points were located in such a way that samples could be obtained of upgradient ground-water quality, downgradient ground-water quality, perched downgradient ground-water quality, surface water quality and leachate. Three wells were monitored during the strip mine landfill study (see Figure 40, Table 12, and Appendix A). They were drilled in July 1978, prior to the first sampling round, with an air rotary down-hole hammer drilling rig and were constructed with 15.24 cm (6.00 in) steel casing to prevent the entry of unconsolidated material.

MP #5 is just north of the strip cut highwall above the landfill; it was located to monitor upgradient regional ground-water quality. To prevent caving of the overburden, which consisted of weathered shale and clay, 5.8 m (19.0 ft) of casing was used. The well was completed to a depth of 48.8 m (160.0 ft) through beds of shale with coal occurring at 25.3 to 25.9 m (83-85 ft) and 37.2 to 38.1 m (122-125 ft).

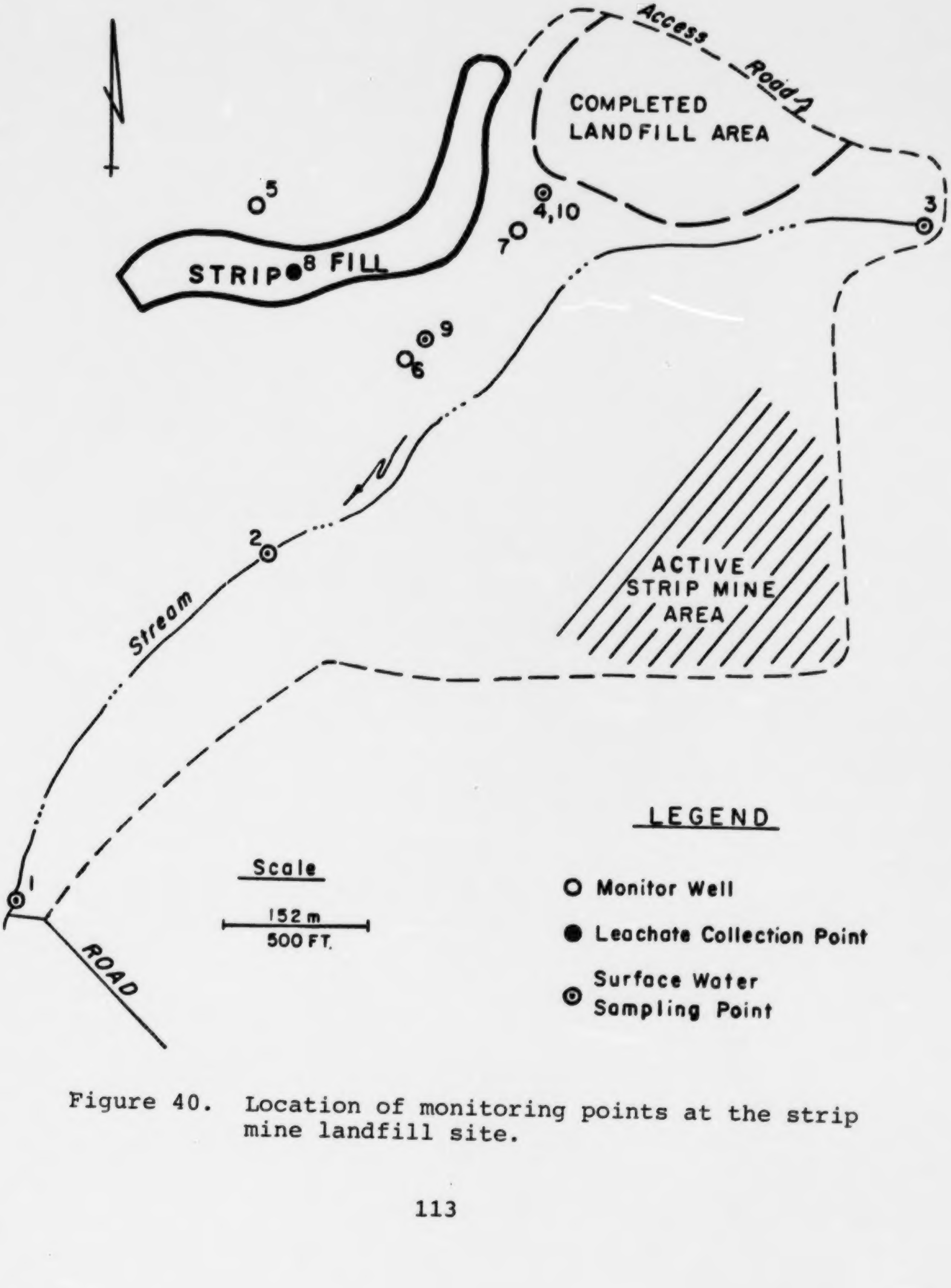

Access Road
COMPLETED LANDFILL AREA
STRIP FILL
ACTIVE STRIP MINE AREA
Stream
ROAD
1
2
3
4,10
5
6
7
8
9
LEGEND
Monitor Well
Leachate Collection Point
Surface Water Sampling Point
Scale
152 m
500 FT.

Figure 40. Location of monitoring points at the strip mine landfill site.

TABLE 12. MONITOR WELL CONSTRUCTION DETAILS - STRIP MINE LANDFILL[a]

MP #	Well depth	Total[b] casing	Type casing	Section slotted	Elevation[c] top of casing	Reference[d]	Surface[e] elevation
5	48.8 (160.0)	5.8 (19.0)	15.24 cm (6.00 in.) Steel	Open Hole	516.41 (1,694.25)	0.38 (1.25)	516.03 (1,693.00)
6	10.7 (35.0)	3.4 (11.0)	15.24 cm (6.00 in.) Steel	3.1- 1.5 (10.0- 5.0)	487.36 (1,598.95)	0.29 (0.95)	487.07 (1,598.00)
7	24.4 (80.0)	4.0 (13.0)	15.24 cm (6.00 in.) Steel	Open Hole	488.08 (1,601.30)	0.40 (1.30)	487.68 (1,600.00)

---

a Measurements in meters (feet) unless otherwise indicated.
b Total casing is equal to the casing in the ground plus casing above ground (Reference).
c All elevations relative to mean sea level.
d Reference above ground surface from which water level measurements are taken.
e Surface elevations estimated from USGS topographic map.

MP #6 is located south of the landfill near the toe of the spoil bank and provided downgradient ground-water samples from a perched water table. During the drilling, backfill, consisting of brown sandy shale, was encountered to a depth of 1.5 m (5.0 ft). A thin layer of coal was present from 1.5 to 1.7 m (5.0-5.5 ft) which was followed by beds of brown shale. The well was completed to a depth of 10.7 m (35.0 ft) and 3.4 m (11.0 ft) of casing was installed. Slots were cut in the lowermost 1.5 m (5.0 ft) of the casing to permit the entry of shallow ground water.

MP #7 is located at the toe of the spoil bank below the base of the east slope of the strip cut. It provided downgradient ground-water samples from the regional water table. It is approximately 183 m (600 ft) northeast of MP #6 at the same elevation and was drilled to a depth of 24.4 m (80.0 ft). The first 4.6 m (15.0 ft) consisted of fill and brown shale; 4.0 m (13.0 ft) of casing was seated in the shale bedrock. A coal seam was encountered from 4.6 to 5.2 m (15.0-17.0 ft). This was followed by sequential beds of grey and brown shale to a depth of 16.8 m (55.0 ft). Another 0.6 m (2.0 ft) coal seam was found from 16.8 to 17.4 m (55.0-57.0 ft). The well was completed in grey shale at a depth of 24.4 m (80.0 ft). During two previous attempts to complete MP #7 approximately 30 m (100 ft) to the northeast of its present location, an auger mine was intercepted. This resulted in a loss of air into the mine and abandonment of the well.

Surface water samples were obtained during the study period from five monitoring points. MP #1 and #2 were stream sampling points downgradient of the landfill. Historical data was available for these monitoring points and for MP #3, an upgradient stream sampling point used only as a source of historical data. MP #9 was a small perched surface water impoundment adjacent to MP #6. MP #4 was a small spring which fed the pond (MP #10) downgradient of the completed landfill area. The leachate seep, MP #8, was present on the completed face of the strip mine landfill.

Hydrogeology of the Strip Mine Landfill Site

The strip mine landfill is located in the Appalachian Plateau which is characterized by roughly parallel beds of coal, shale and sandstone. The geologic structure of these rocks controls the occurrence and movement of ground water in the study area. The site is being developed along the highwall of an inactive strip mine. Landfill operations are approximately recreating the original contour of the site. In addition to stripping, the area has open auger mines extending into the coal which may have caused selective drainage of areas near the site. Because of the widely varying permeability of interbedded coals, shales and sandstones, perched water tables are common; indeed, a perched water table is located just below the strip mine landfill (MP #6).

Hydrologic data for the study area is comparatively sparse because the site is relatively remote and the area around it is not highly developed. The basin in which the site is located encompasses a large area and has significant climatic variability. Therefore, the water budget developed for this site is based on stream gaging records for a 528-square-mile basin located immediately to the south of the site. This basin has climatic conditions which better approximate those of the site, i.e., an average precipitation of 104.1 cm (41 in) per year. Approximately 53 percent of the precipitation (PPT) runs off either as ground-water base flow (GW) or direct surface runoff (SW), and the remaining 47 percent is lost to evapotranspiration (ET). Examination of dry period, low flow records for the stream indicates that the base flow in the area, equivalent to ground-water recharge (GW), is approximately 22 percent of the precipitation. The water budget for the site is therefore:

$$\begin{array}{ccccccc} \text{PPT} & = & \text{ET} & + & \text{SW} & + & \text{GW} \\ 104.14\ \text{cm} & = & 48.95\ \text{cm} & + & 32.28\ \text{cm} & + & 22.91\ \text{cm} \\ (41.00\ \text{in}) & = & (19.27\ \text{in}) & + & (12.71\ \text{in}) & + & (9.02\ \text{in}) \end{array}$$

This budget is the best estimate which can be developed for a mass balance at the landfill and can be used to estimate leachate generation by the strip mine landfill. Because the landfill is being returned to the approximate original grade with local materials being used for cover and revegetation with local grasses, the landfill area may be expected to react similarly to the basin as a whole. A leachate generation estimate for the strip mine site has been developed utilizing the regional annual recharge rate of 22.91 cm (9.02 in) and applying it to the 5.7 ha (14 ac) at the landfill site. This estimate indicates that 13,059 m^3 (10.52 ac-ft) of leachate should be generated per year by this site.

Figure 41 shows a cross section of the strip mine landfill taken on line AA' shown on Figure 42 passing northwest to southeast through MP #5 and #6. Depth to water in the monitoring points at the site varied less than 0.6 m (2 ft) during the study period (see Appendix C). The three monitoring wells constructed for the study measure water levels in two separate flow systems. MP #6 monitors a perched flow system located 1.5 to 1.8 m (5-6 ft) below the ground surface on the bench below the strip mine landfill. MP #5 and #7 monitor the regional flow system. MP #5, located on high ground above the site, had depth to water ranging from 38.1 to 38.4 m (125-126 ft) while MP #7, located on the bench below the landfill, had depth to water ranging from 13.4 to

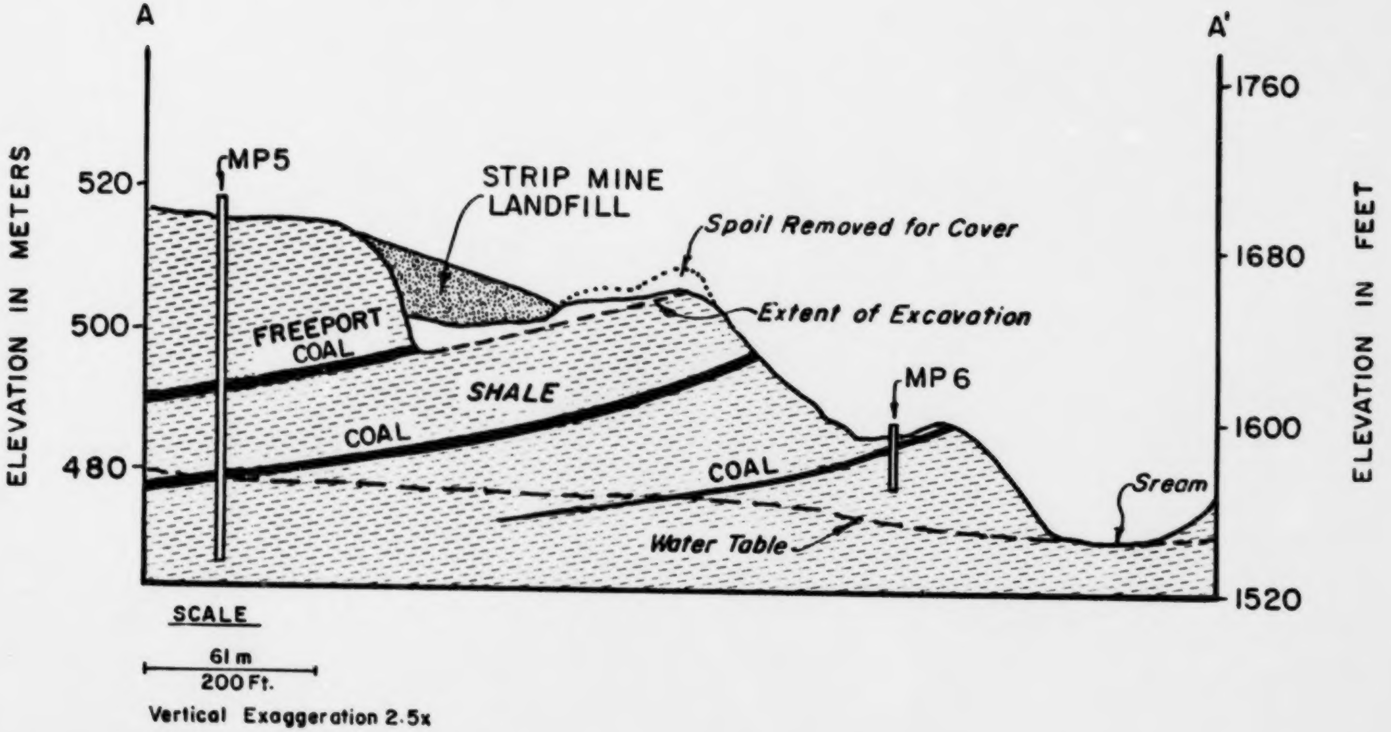

A
A'
ELEVATION IN METERS
520
500
480
ELEVATION IN FEET
1760
1680
1600
1520
MP5
STRIP MINE LANDFILL
Spoil Removed for Cover
Extent of Excavation
FREEPORT COAL
SHALE
COAL
MP6
COAL
Sream
Water Table
SCALE
61 m
200 Ft.
Vertical Exaggeration 2.5x

Figure 41. Cross section of the strip mine landfill site. (Water table locally perched above coal seams.)

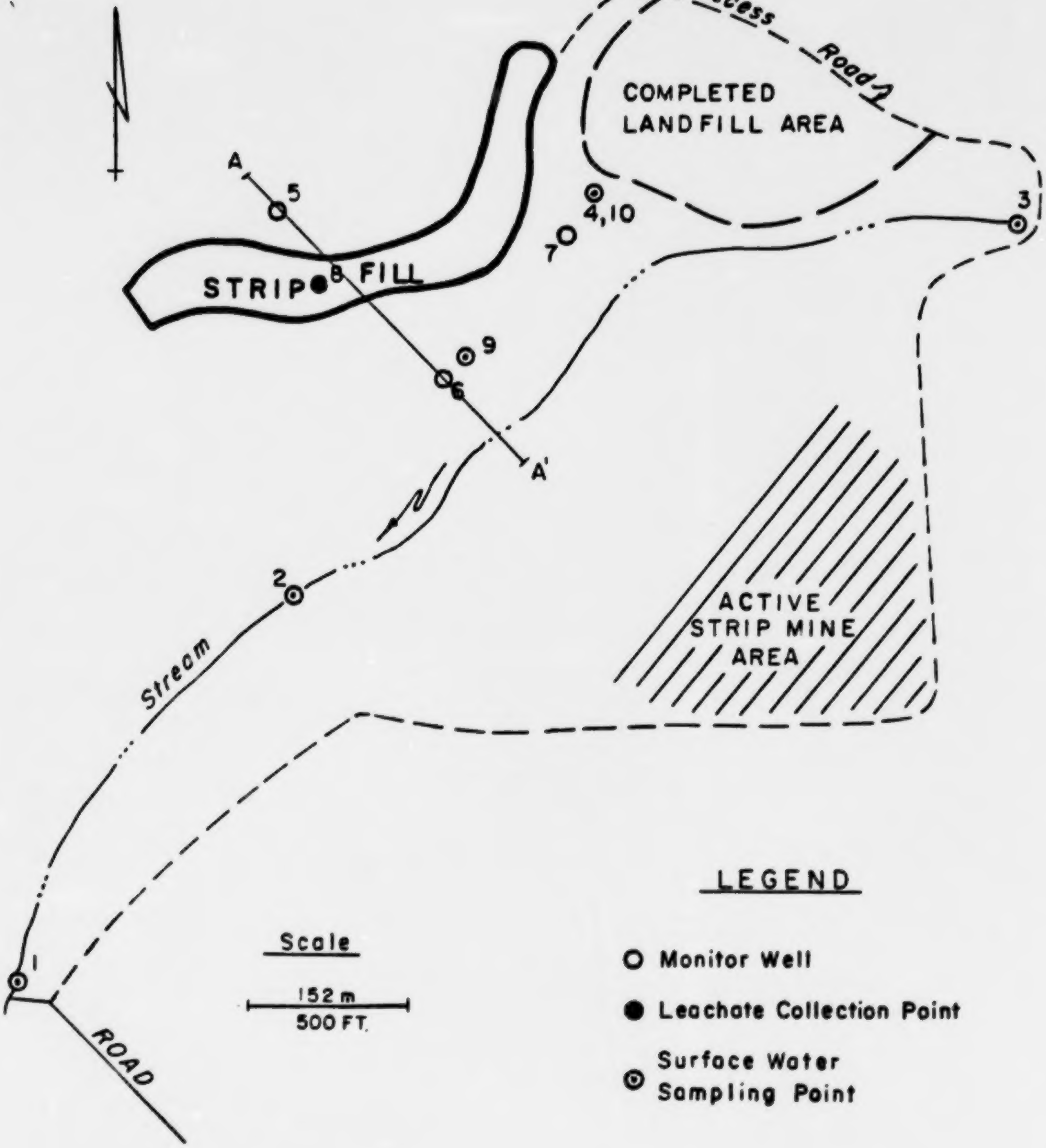

Access Road
COMPLETED LANDFILL AREA
STRIP FILL
A
A'
1
2
3
4,10
5
6
7
8
9
Stream
ACTIVE STRIP MINE AREA
ROAD
Scale
152 m
500 FT.
LEGEND
Monitor Well
Leachate Collection Point
Surface Water Sampling Point

Figure 42. Map showing the location of the line of cross section, AA'.

13.7 m (44-45 ft). Depth to water directly beneath the landfill is approximately 24.1 to 24.4 m (79-80 ft).

The water table map based on three data points, (see Figure 43) shows the regional flow system and also indicates the elevation of the perched flow system where it is monitored at MP #6. Ground water flows to the south and discharges into the stream. The ground-water flow path may have been altered by auger mining in the vicinity of MP #7. Leachate produced by the landfill percolates through the landfill base which is composed of clayey spoil material mixed with inert industrial waste dust and enters the ground-water flow system. The landfill base is relatively thin compared to the volume of refuse above it allowing minimal attenuation of the leachate; thus the chemical character of leachate leaving the strip mine landfill is not significantly altered by adsorption. However, leachate is diluted as it moves through the ground-water flow system.

Water Chemistry at the Strip Mine Landfill Site

The complex hydrogeology associated with the strip mine makes it difficult to determine the extent of the area affected and to trace the movement of pollutants. The bedrock dips toward a large syncline to the northwest, but the ground-water table, 25 m (82 ft) below, slopes gently in the opposite direction toward the stream. Precipitation percolating through the landfill moves first northwest along bedding planes until it reaches the water table where it then moves to the southeast with the ground water toward the stream. Perched water tables are present due to the underclays associated with coal. Several fracture zones and auger mines exist which may redirect the movement of ground water.

Assessment of the impact of the strip mine landfill on local water chemistry is complicated further by the effect of acid mine drainage. Exposure of the sulfurous shales associated with coal will often increase the acidity of ground water, decrease its alkalinity, and increase concentrations of iron and sulfate. Landfills produce a wider range of contaminants which assist in distinguishing the effects of leachate.

Leachate (MP #8) was sampled only during the spring round when recharge caused a seep to flow on the side of the landfill. The pond (MP #10) was sampled during the December and February rounds and the spring which feeds it (MP #4) was sampled during the May and August rounds. The small surface impoundment associated with the perched water table (MP #9) was also sampled only during the spring and summer. The upgradient well (MP #5) could not be sampled in December 1978.

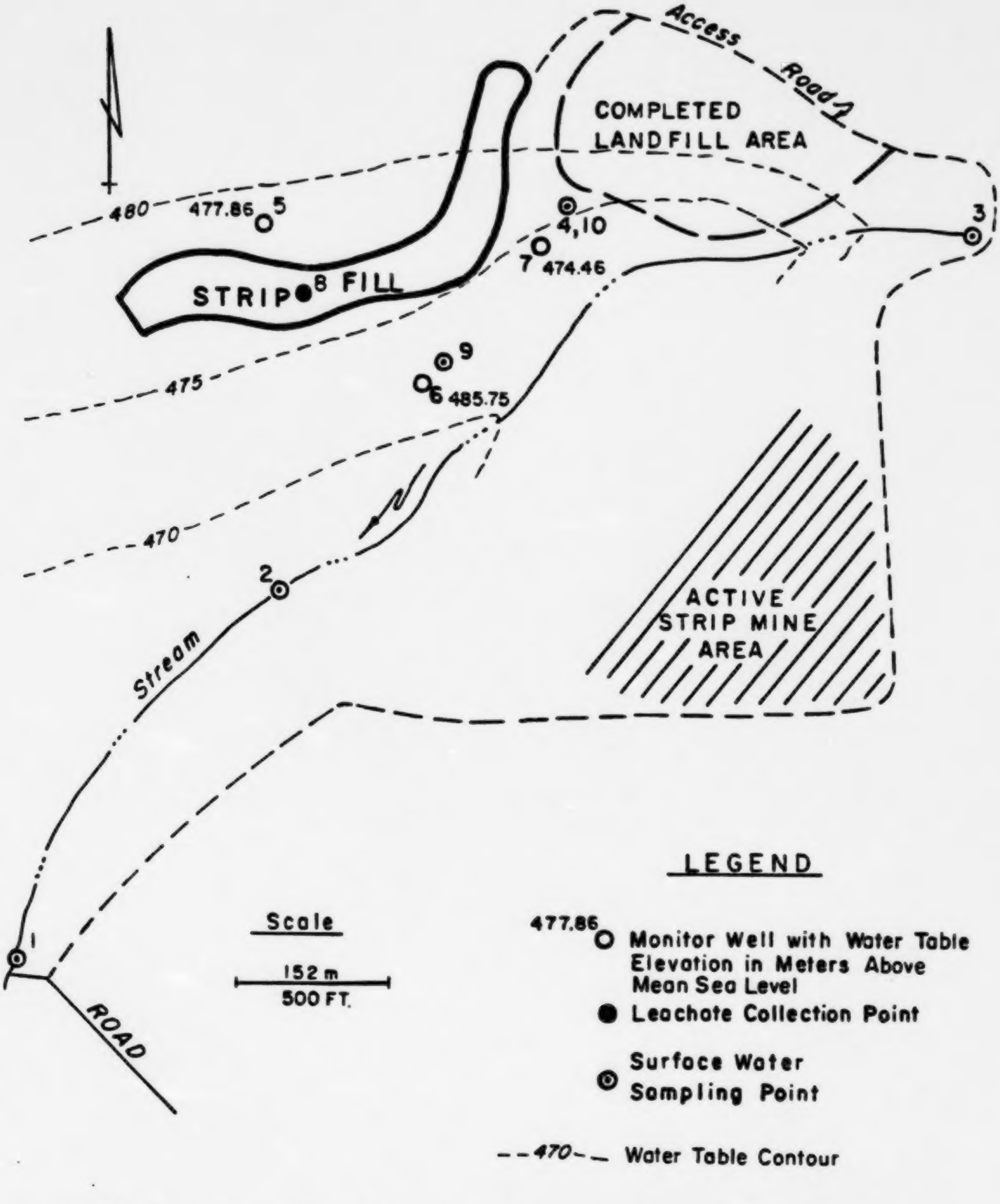

Access Road
COMPLETED LANDFILL AREA
480
477.86 5
4,10
7 474.46
3
STRIP 8 FILL
9
6 485.75
475
470
2
Stream
ACTIVE STRIP MINE AREA
1
ROAD
LEGEND
Scale
152 m
500 FT.
477.86 O Monitor Well with Water Table Elevation in Meters Above Mean Sea Level
● Leachate Collection Point
⊙ Surface Water Sampling Point
--470-- Water Table Contour

Figure 43. Map of water table at the strip mine landfill site.

Bar graphs for six parameters, alkalinity, acidity, TDS, TKN, COD, and TOC, are shown on Figures 44, 45, and 46 (also, see Section 2). Frequent reference should be made to the results of water chemistry analyses presented in Appendix E. The actual impact of the landfill itself can be assessed most accurately with the organic indicators, TKN, COD, and TOC. They indicate that all the monitoring points except, perhaps, MP #6 (the well in the perched water table) have been affected by the landfill.

Leachate (MP #8) shows a strongly alkaline character with an elevated alkalinity value of 5620 mg/l and a very negative acidity value of -3,000 mg/l (see Figure 44).

The upgradient well (MP #5) also has a high value for alkalinity (318 mg/l) and a low value for acidity (-329 mg/l). Quarterly data demonstrates that concentrations in this well have doubled in the course of the present study (see Appendix E). The downgradient well (MP #7) has a slightly lower alkalinity value (243 mg/l) and less negative acidity value (-261 mg/l).

The perched water table well (MP #6) has a low value for alkalinity (19.5 mg/l) and an only slightly negative acidity (-4 mg/l) while the surface expression of this perched water table (MP #9) shows 40 mg/l for alkalinity and -30 mg/l for acidity. The increase in concentrations in MP #9 over MP #6 is probably the result of runoff being collected at MP #9 since runoff to this point contacts both mine spoil and previously landfilled areas.

The spring (MP #4) shows a high alkalinity (323 mg/l) and low acidity values (-350 mg/l). The contaminated water issuing from the spring is diluted by the pond (MP #10) which has values of 73 mg/l for alkalinity and -66 mg/l for acidity. The concentrations at MP #10 reflect the average of widely differing values from two quarterly rounds; December 1978 showed low alkalinity and a positive acidity value while February 1979 showed high alkalinity and a negative acidity value (see Appendix E). There was considerable snow melt just prior to the February sampling round and the greater alkaline character of the water at that time may be attributable to the effects of leachate.

The two stream monitoring points, MP #2 (downstream) and MP #1 (farther downstream), show a decrease in concentrations with movement downstream. Alkalinity for MP #2 and #1 is 111 mg/l and 91.5 mg/l, respectively; acidity is -111 mg/l and -88 mg/l. This relationship suggests that the source for these parameters lies upstream and that there is progressive dilution in the downstream direction.

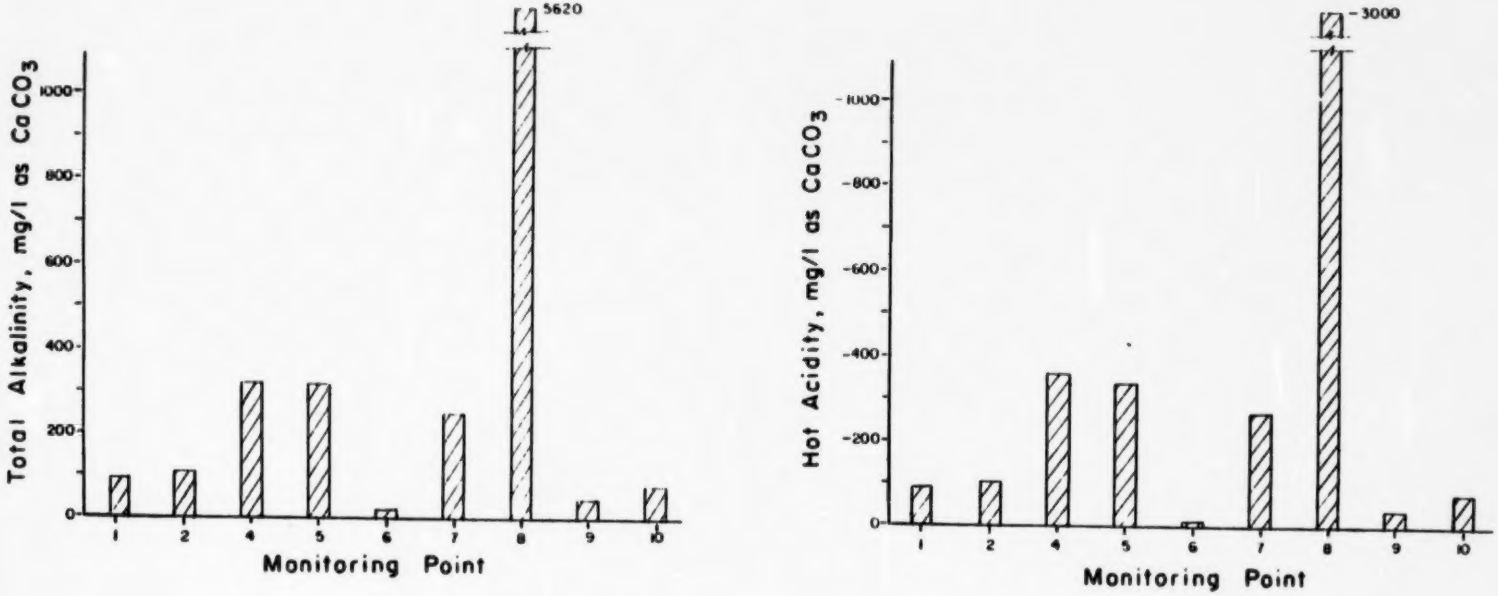


Figure 44. Bar graphs for alkalinity and acidity at the strip mine landfill site.

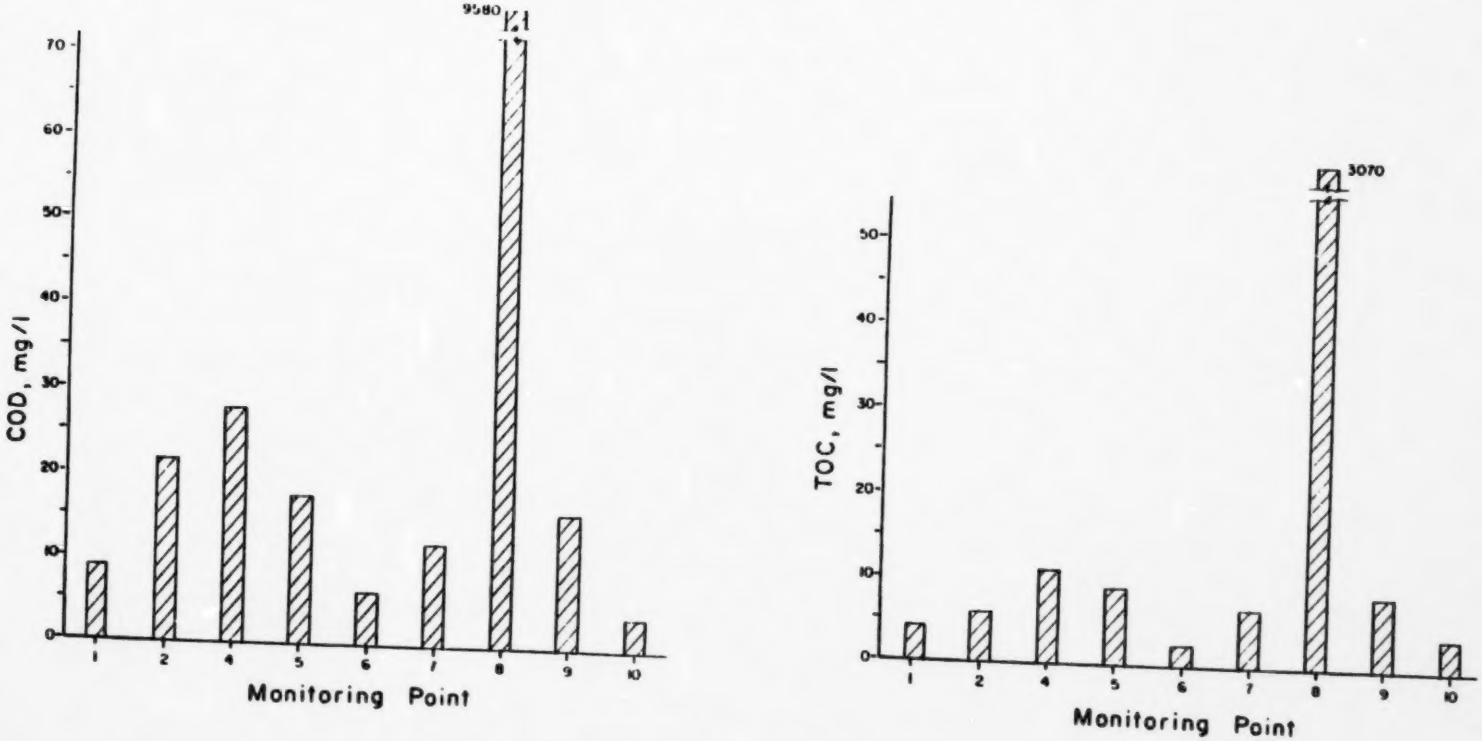


Figure 46. Bar graphs for COD and TOC at the strip mine landfill site.

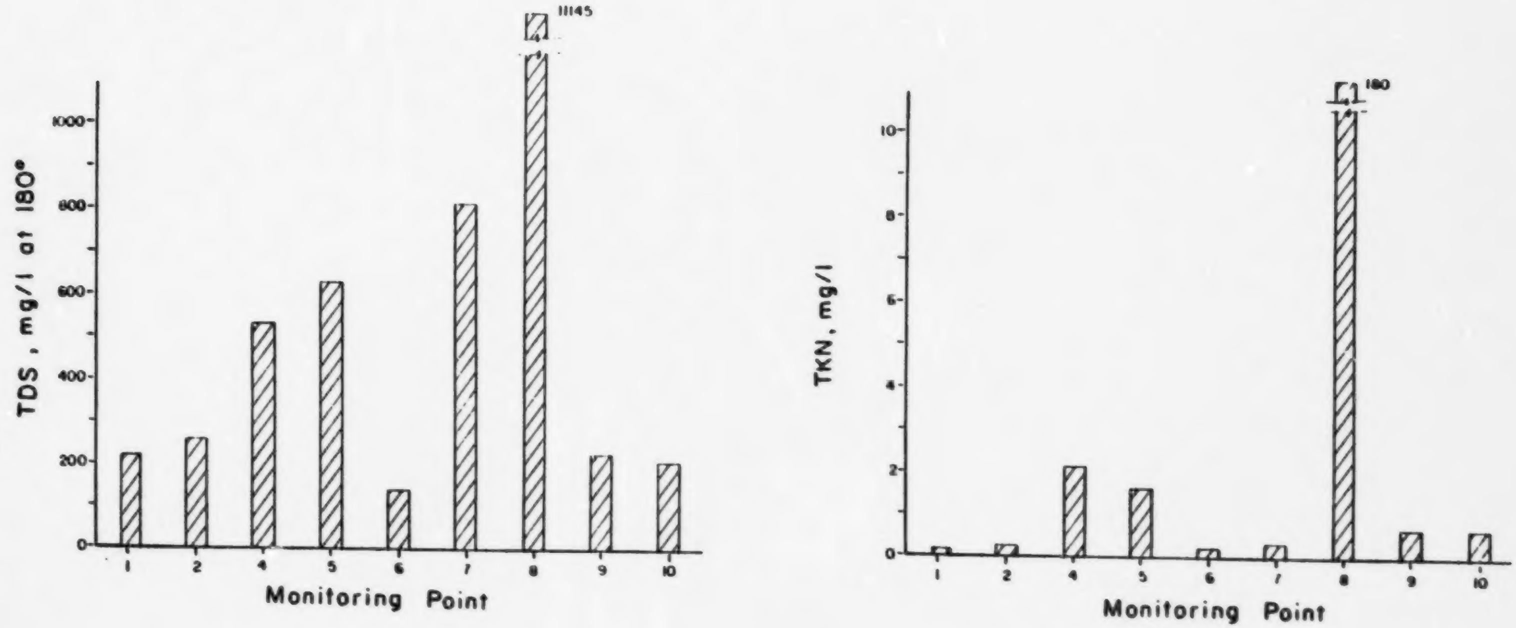


Figure 45. Bar graphs for TDS and TKN at the strip mine landfill site.

TDS shows many of the same relationships as the previously discussed parameters (see Figure 45). Leachate (MP #8) is very elevated with 11,145 mg/l. The two deep wells are also elevated; MP #5 has 623 mg/l (concentrations increased with every quarter), and MP #7 has 817 mg/l.

The perched water table exhibits mean TDS values of 141 mg/l at MP #6 and 219 mg/l at MP #9. The spring (MP #4) and pond (MP #10) show 527 mg/l and 206 mg/l, respectively. The stream monitoring points, MP #1 and #2, are 225 mg/l and 255 mg/l, respectively.

Because TKN is exclusively an organic indicator, it clearly shows the effects of the leachate on the ground water. TKN in the leachate is elevated (180 mg/l). The upgradient well (MP #5) has a relatively high value of 1.60 mg/l; the downgradient well (MP #7) has a significantly lower value of 0.28 mg/l. The quarterly data (see Appendix E) indicates that MP #7 is generally less affected than MP #5 by the presence of the landfill except at times of high recharge (the value for the spring sampling round is greater 0.71 mg/l).

The perched water table has a low TKN value of 0.20 mg/l for MP #6; MP #9 has a significantly higher mean concentration, 0.70 mg/l. This suggests that surface runoff collected in MP #9 has been contaminated by leachate as it moved downslope.

The spring (MP #4) is elevated with 2.15 mg/l TKN; this value is higher than that of MP #5 (1.60 mg/l). The probable source of elevated concentrations of reduced nitrogen species is the completed landfill area northeast of MP #4 (see Figure 40). The pond (MP #10) shows a slightly lower value, 0.65 mg/l, but there is a considerable difference between the December 1978 and February 1979 values.

Though their TKN concentrations are small, the stream monitoring points indicate that water contaminated by leachate is reaching the stream. MP #2, closer to the source, has a higher concentration (0.25 mg/l) whereas MP #1, after dilution from springs on the lower reaches of the stream, has a lower concentration of 0.16 mg/l.

COD and TOC reinforce many of the relationships seen in the former parameters (see Figure 46). COD concentrations in the leachate are elevated (9,580 mg/l). Again, concentrations are higher in the upgradient well (MP #5) than in the downgradient well (MP #7) with values of 17.33 mg/l and 11.73 mg/l, respectively.

MP #6 and #9 are 6.48 mg/l and 16.0 mg/l, respectively. MP #4 again shows a higher value than MP #5 with 27.50 mg/l and MP #10 is much lower with 3.95 mg/l. There are decreasing concentrations downstream with MP #2 (21.50 mg/l) and MP #1 (8.73 mg/l).

TOC shows a similar pattern. Leachate (MP #8) is elevated with a value of 3,070 mg/l. MP #5 and MP #7 have concentrations about 2.5 orders of magnitude lower than leachate with values of 8.8 mg/l and 6.8 mg/l, respectively.

MP #6 has 2.3 mg/l TOC while MP #9 is elevated above that with 8.2 mg/l. The spring (MP #4) has a high concentration of 10.9 mg/l while the pond has only 3.5 mg/l. The stream shows less of a contrast between MP #2 and #1 than with the previous parameter with 5.9 mg/l and 4.1 mg/l, respectively.

The bar graphs exhibit the following trends consistently. The upgradient well, MP #5, is always elevated relative to the downgradient well, MP #7, except for TDS. MP #5 shows increasing concentrations of alkalinity, acidity, and TDS but the organic indicators remained stable throughout the course of the study (see Appendix E). Except when influenced by spring recharge, MP #7 showed a more acid character than MP #5 with lower alkalinity values, less negative acidity values, and higher TDS. During the spring round, the sulfate concentration dropped and there were greater alkalinity and lower acidity values. The increased influence of leachate during the month of May 1979 is confirmed by a corresponding rise in TKN, TOC, COD, sodium, and manganese.

While MP #4 is equal to or less than MP #5 in alkalinity, acidity, and TDS, it is greater than MP #5 in the organic parameters TKN, COD, and TOC. This reflects the more advanced stage of decomposition of organic matter in the refuse in the completed landfill area which influences MP #4. The pond (MP #10) had considerably lower concentrations and seemed to be greatly influenced by such runoff events as the February snow melt.

Surface runoff is somewhat contaminated by leachate. This is indicated by the higher organic concentrations found in the surface catchment, MP #9, in contrast with the adjacent shallow well, MP #6. The consistent decrease in the downstream direction (MP #2 and #1) observable for all parameters considered in the present study indicates that the landfill and strip mine operations are significant sources of pollutants.

The Stiff diagrams confirm many of the relationships seen in the bar graphs (see Figure 47). Iron, manganese, and sulfate are characteristic of both leachate and acid mine drainage whereas sodium, zinc, chloride, and phosphate are indicative of leachate.

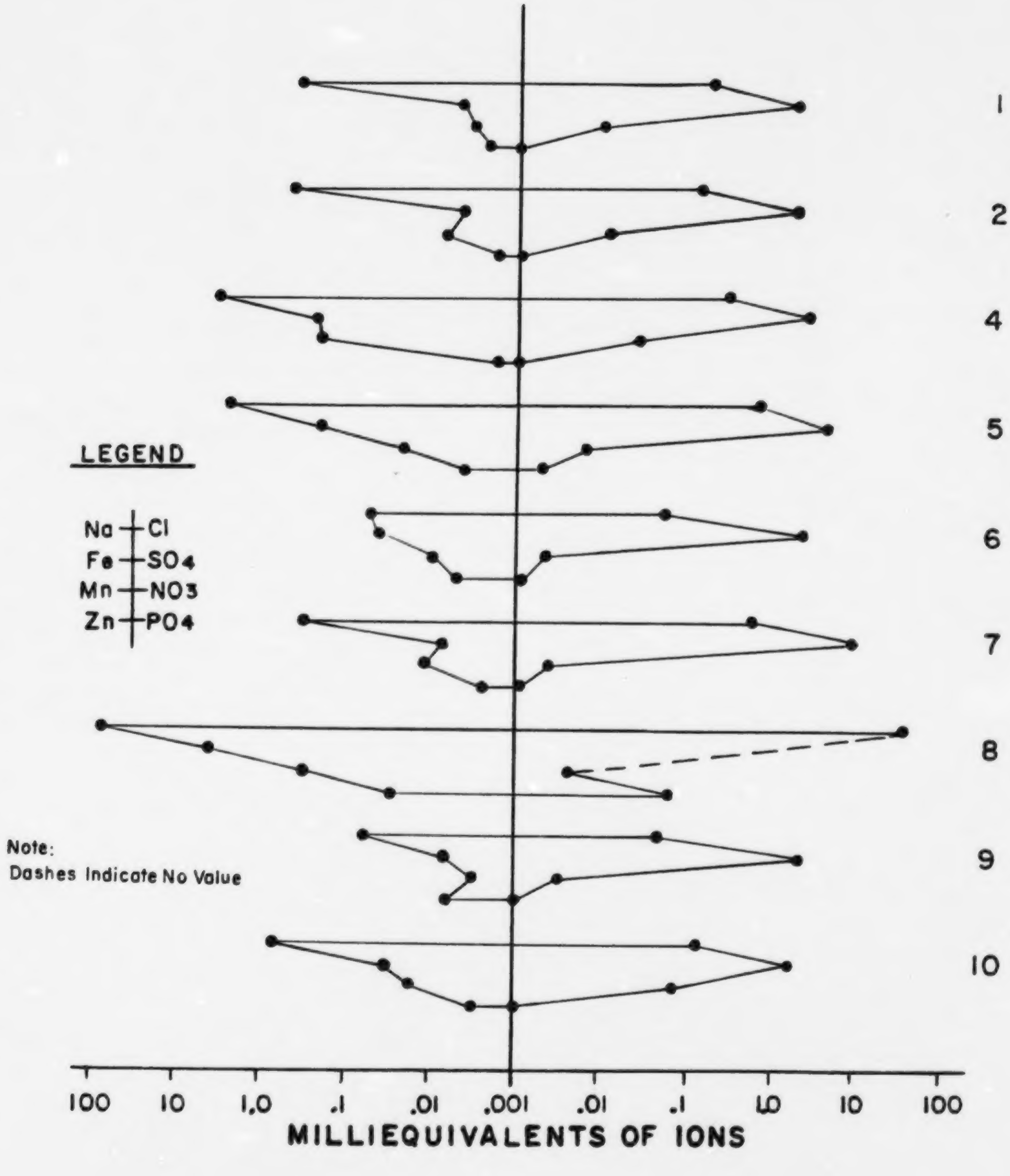


Figure 47. Modified stiff diagrams showing averaged results of chemical analyses at the strip mine landfill site.

The diagram for the leachate (MP #8) shows considerable amounts of all parameters except nitrate. The sulfate value is absent because of chemical interference during the analysis of the single sample (May 1979). The diagram for MP #5 is similar in shape to that of MP #8 which clearly indicates the influence of leachate. Phosphate has attenuated more rapidly than the other parameters but is still present in significant amounts. At the other monitoring points, only trace amounts of phosphate were present.

The spring (MP #4) also shows the profile of leachate except that it has relatively more manganese and nitrate and less zinc. The nitrate probably represents oxidized organic nitrogen from the leachate. The diagram for the pond (MP #10) has a similar shape to that for the spring; nitrate has increased indicating further oxidation of organic and reduced nitrogen from the leachate.

The perched water table (MP #6) shows a profile more typical of acid mine drainage than of leachate. Compared to the previously discussed monitoring points, MP #6 is relatively higher in sulfate and lower in sodium and chloride values. The diagram for the surface expression of this perched water table (MP #9) changes only slightly from that for MP #6; iron and manganese have decreased.

The downgradient well (MP #7) shows the affects of both acid mine drainage and leachate. The shape of its diagram is similar to that for MP #6 except that sodium, chloride, and sulfate concentrations have risen because of the influence of leachate.

The diagrams for the stream monitoring points (MP #1 and #2) are similar to each other. The effect of leachate can be seen in the slightly higher sodium and chloride concentrations at these monitoring points when compared with MP #6.

The Stiff diagrams for monitoring points at the strip mine landfill indicate that sodium provides the best single indication of leachate and is most useful in distinguishing the effects of leachate from acid mine drainage. Some trends that are not evident in the Stiff diagrams but that are useful in the interpretation of sodium are available in Appendix E. Concentrations of sodium in MP #5 are high and increased steadily throughout the study; those in MP #7 are lower (excluding a high value in May). MP #4 has high sodium concentrations and MP #10 showed a high sodium concentration during February.

The Stiff diagrams show that the leachate contains considerable amounts of all the ionic species considered and that MP #4, #5, and #10 have been affected by leachate. The ground water at MP #7 has been affected both by acid mine drainage and by leachate. The stream (MP #1 and #2) and the perched water table (MP #6 and #9) show relatively little impact from the landfill.

The nitrogen ratios shown on Figure 48 further confirm the previously discussed relationships among the monitoring points. The leachate (MP #8) has a high ratio of 750; it is the source of reduced nitrogen species. The upgradient well (MP #5) has the highest value among the wells (3.87) while the downgradient well (MP #7) is somewhat lower (1.90). This indicates more reducing conditions at MP #5 and shows a migration of leachate to MP #5. Leachate also moves toward MP #7 in the dominant downgradient direction of ground-water flow.

The ratio for MP #4 is lower than that for either MP #5 or MP #7. However, concentrations of both TKN and nitrate are higher in MP #4 than at any of the other monitoring points except leachate; this indicates that, because of constant contact with the atmosphere, much of the reduced nitrogen is oxidized to nitrate. The nitrogen ratio for the pond (MP #10) is even lower (0.15) primarily because of high nitrate concentrations; this indicates further oxidation of reduced species. The surface water point (MP #9) has a ratio more than two times that of the adjacent well, MP #6, with 3.78 and 1.54, respectively. This difference indicates that a slightly more reducing environment exists at MP #9 and that the surface water is influenced by leachate carried in runoff from the landfill. Both nitrogen ratios for the stream are small and decrease with distance downstream from the landfill. The ratio at MP #2 is 0.36 and at MP #1, 0.27. It appears that ground water contaminated by the landfill enters the stream.

Historical data is available only for the stream monitoring points, MP #1, #2, and #3, (see Appendix D). Many of the parameters considered in the present study showed increases moving from MP #3 (upstream) to MP #2 and then a decrease to MP #1 farther downstream. The parameters which support this trend are alkalinity, specific conductance, COD, and total solids. These parameters also tend to have higher values in the summer months. Sulfate is generally stable or increases downstream; iron is stable or decreases downstream. This pattern reflects an influx of contaminants from the strip mine landfill. Most of the trends were not established until after the end of 1975 which may be a function of the age and quantity of the refuse in the landfill.

Ground-water quality as observed at the strip mine landfill monitoring points is affected by various factors.

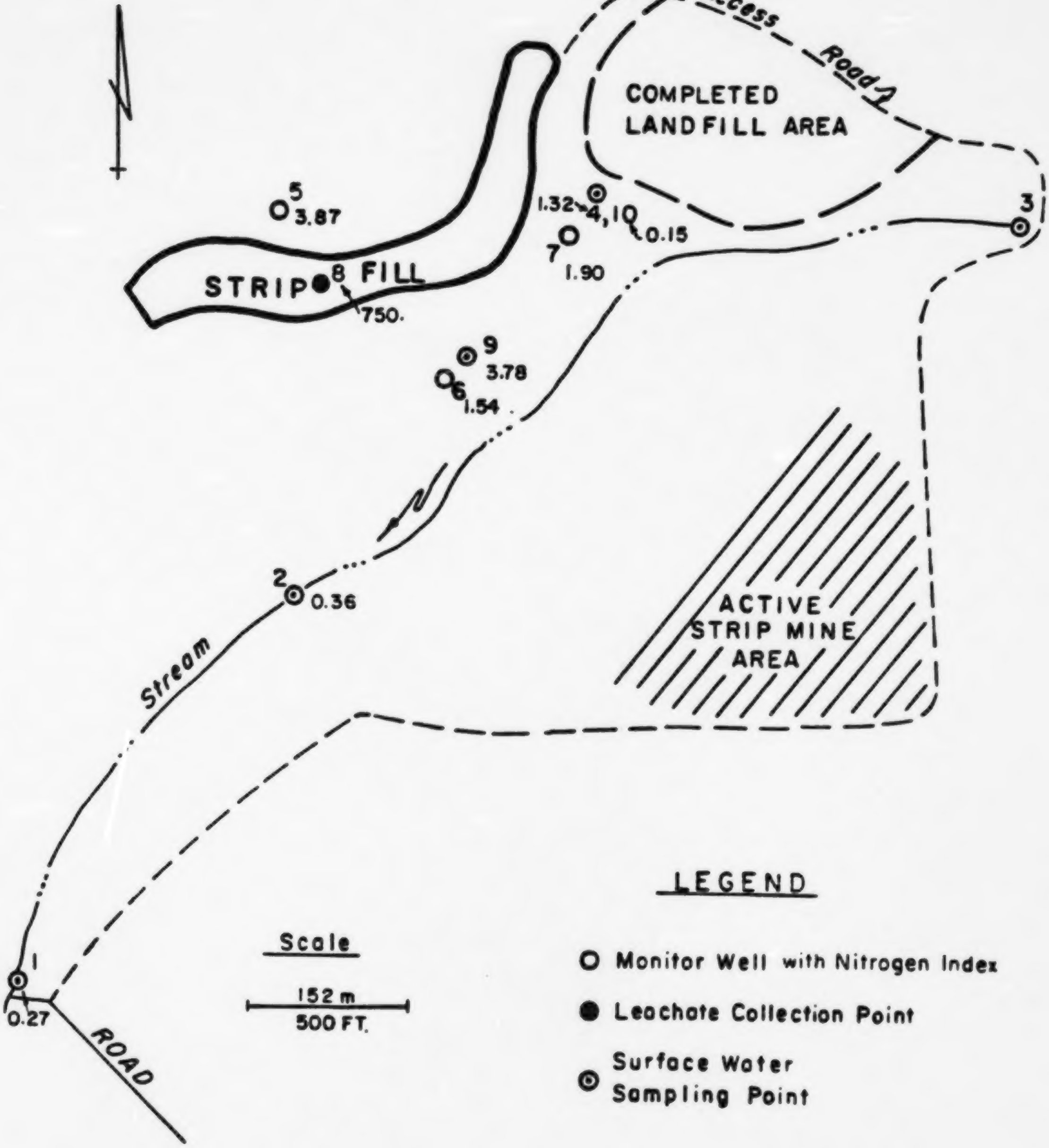

Access Road
COMPLETED LANDFILL AREA
5
3.87
1.32
4, 10
0.15
3
7
1.90
STRIP 8 FILL
750.
9
3.78
6
1.54
2
0.36
ACTIVE STRIP MINE AREA
Stream
1
0.27
ROAD
LEGEND
Scale
152 m
500 FT.
○ Monitor Well with Nitrogen Index
● Leachate Collection Point
⊙ Surface Water Sampling Point

Figure 48. Nitrogen index showing the ratio of organic nitrogen plus ammonia nitrogen (TKN) to nitrite plus nitrate nitrogen ($NO_2 + NO_3$).

The bedrock in the region is primarily shale which is a basic reason that the ground water in the area has significant iron, sulfate, and TDS concentrations. Strip mining operations at the landfill site have served to contribute quantities of minerals to the local ground water. The strip mine landfill produces a leachate of moderate strength which further degrades ground water quality and an insufficient soil mantle beneath the landfill allows leachate to reach the ground-water table with only minor attenuation. Significant concentrations of parameters considered in the present study found in the upgradient well (MP #5) suggest that leachate percolating through the base of the landfill moves northwest down bedding planes. The steady rise in concentrations of most parameters at MP #5 might indicate a long-term pattern of increasing quantities or stronger leachate reaching the ground water. This trend may be a function of the relative youth of the landfill; 85 percent of the refuse has been landfilled between 1976 and 1980.

The impact of the landfill on surface water has been minimal. Surface runoff retained at MP #9 shows minor effects of leachate. The stream is a ground-water discharge area and movement of contaminated ground water to the stream is facilitated by fractures in the bedrock. The relatively minor concentrations of parameters in the stream decrease rapidly in the downstream direction. The influence of leachate from the strip mine landfill has remained localized because of the hydrogeologic characteristics of the site.

PERMITTED SANITARY LANDFILL

The permitted sanitary landfill was constructed by the trench technique in which refuse is placed in trenches and the excavated soils are used as cover; no volume reduction techniques were employed before to the landfilling.

Topographic Position

The landfill is situated on a topographic divide between a creek and an unnamed tributary of that creek, 0.8 km (1/2 mile) west of an unincorporated village (see Figure 49). South and east of the site there is a large swampy bottom land where lake sediments occupy a glacially widened valley. West of this valley, there are relatively steep sloping bedrock valley walls. Interfluves are generally broad and covered with a mantle of glacial till. Where side valleys discharged to the old lake bottom, glacially-derived deltaic and alluvial sediments occur.

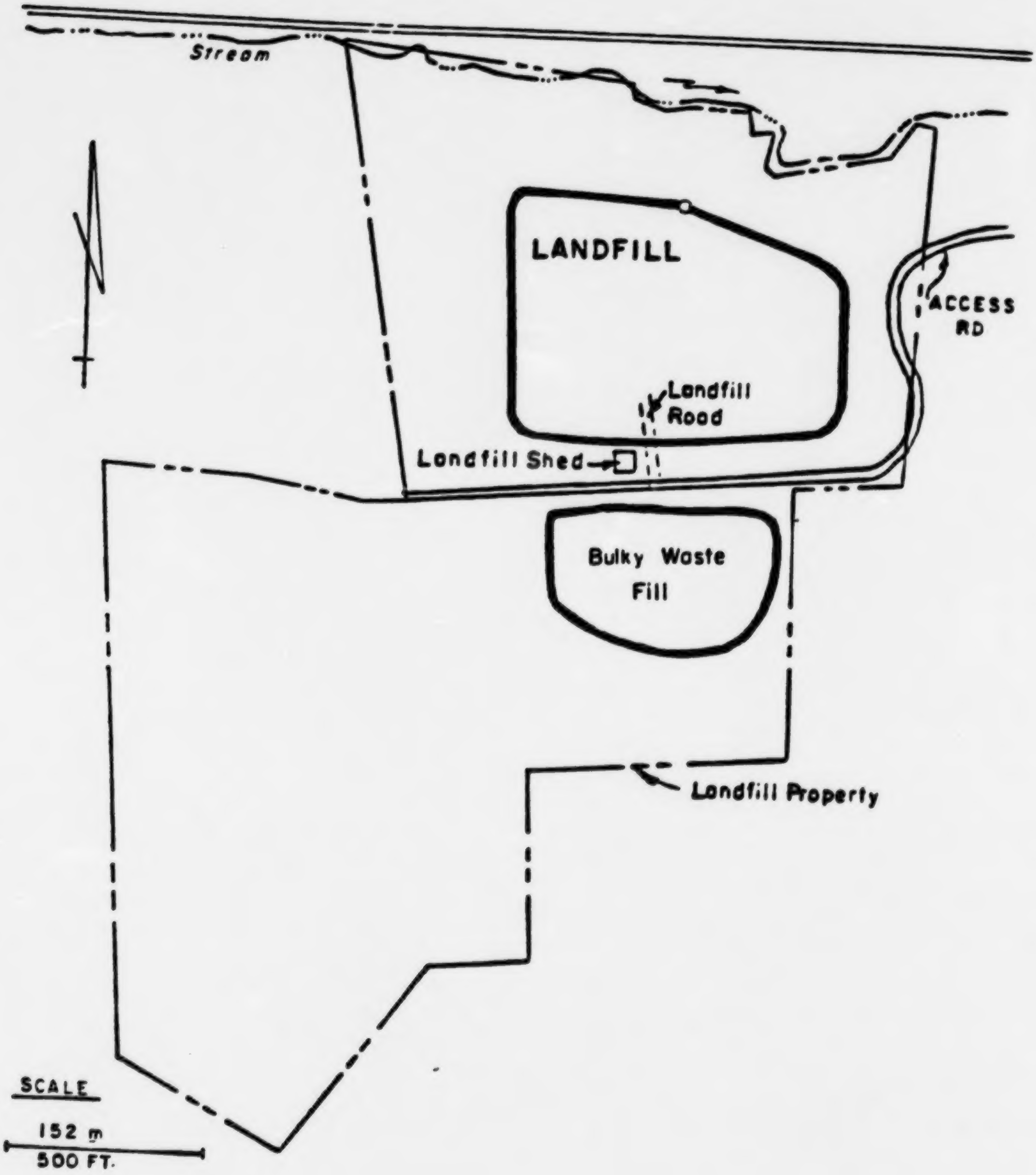

Stream
LANDFILL
ACCESS RD
Landfill Road
Landfill Shed
Bulky Waste Fill
Landfill Property
SCALE
152 m
500 FT.

Figure 49. Map of permitted sanitary landfill site.

Climate

The climate at the landfill is humid continental and is characterized by relatively dry, cold winters and warm to hot, wet summers. Based on data compiled by the U.S. Weather Bureau at a nearby weather station for a 30-year period of record, the mean annual precipitation for the area is 78.60 cm (30.94 in). The precipitation varies from a normal (average for period of record) low of 4.45 cm (1.75 in) in February to a normal high of 8.23 cm (3.24 in) in July (see Figure 50 and Table 13).

May through July are the wettest months with average precipitation in excess of 7.5 cm (2.6 in), while January and February are the driest with less than 5 cm (2 in). Snow falls from December to March, averaging approximately 140 cm (55 in) per year, and generates large amounts of spring runoff.

Precipitation during the twelve-month study period was 4.94 cm (1.94 in) above normal. The months of September 1978, October 1978, December 1978 through February 1979 and August 1979 were wetter than normal. Below normal precipitation occurred in November 1978 and from March 1979 through July 1979.

The mean annual temperature is 9.4C (48.9F) with a normal low of -3.2C (26.2F) in February and a normal high of 22.3C (72.2F) in July. Mean annual lake evaporation is approximately 69 cm/yr (27 in/yr).

Geology and Soils

The landfill is situated in the Appalachian Plateau and is underlain by Upper Devonian bedrock consisting entirely of shale and mudstone units. Two major groups have been mapped in the vicinity of the site: the Sonyea Group and the Lower West Falls Group. The Sonyea Group includes the Cashaqua and Middlesex Shales, crops out north of the site, forms steep slopes in the vicinity of the site, and underlies the northern portion of the landfill. The Lower West Falls Group includes the Lower Beers Hill Shale and the Dunn Hill, Millport, and Moreland Shales and underlies the southern part of the site.

An outcrop north of the site is cross-laminated, grey to green, fissle shale of the Upper Sonyea Group. The beds are essentially horizontal at this location. Prominent joint sets strike N 28°W with a dip of 84°E and N 85°W with a vertical dip. Much of the outcrop exhibits a "pencil"-type fracture cleavage. No water was observed seeping from the outcrop.

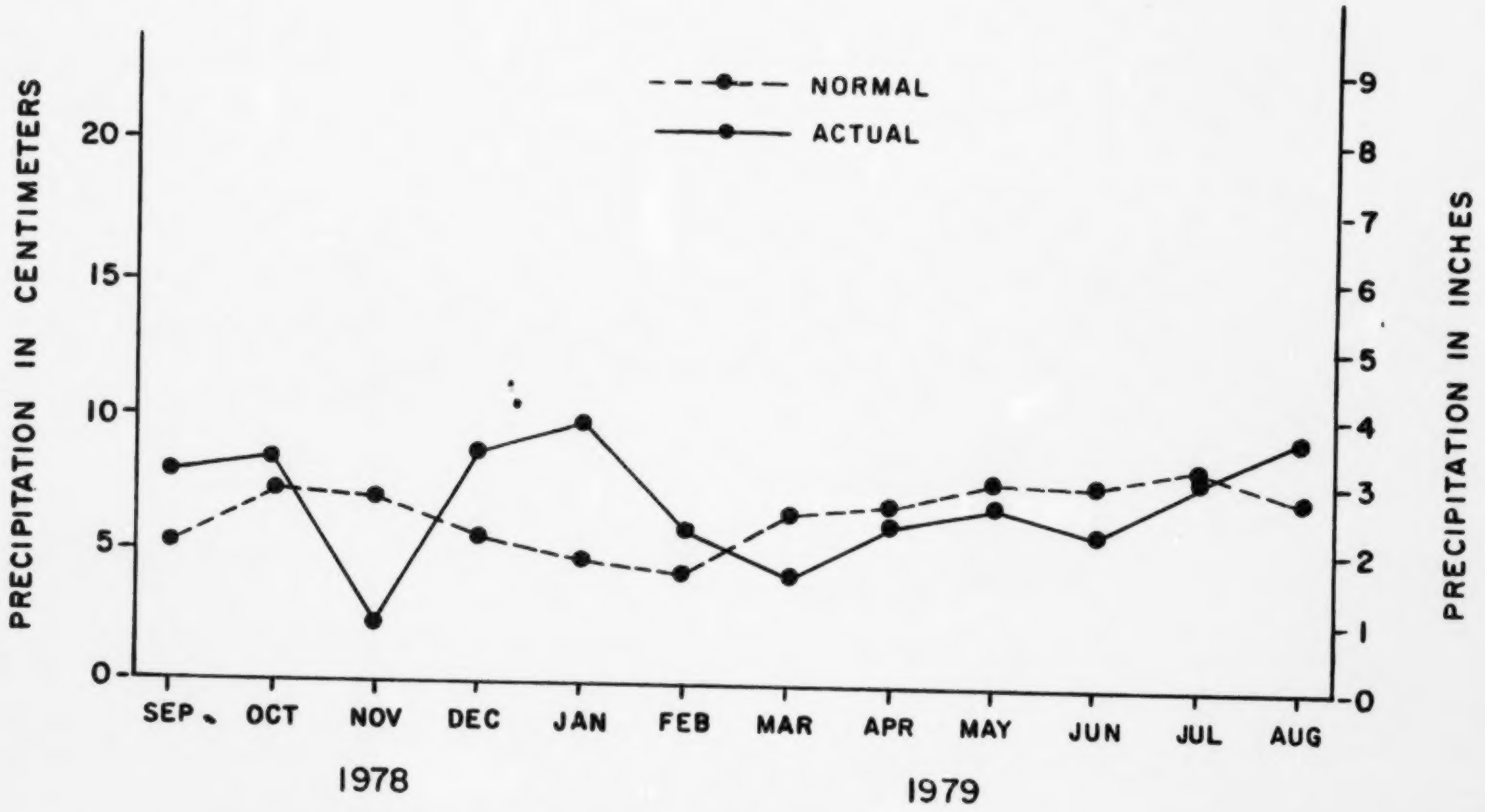


Figure 50. Graph of precipitation at the permitted sanitary landfill.

TABLE 13. MONTHLY PRECIPITATION DATA[a] PERMITTED SANITARY LANDFILL

Date	Normal	Actual	Departure from normal
9/78	5.33 (2.10)	7.90 (3.11)	2.57 (1.01)
10/78	7.42 (2.92)	8.36 (3.29)	0.94 (0.37)
11/78	6.96 (2.74)	2.49 (0.98)	-4.47 (-1.76)
12/78	5.33 (2.10)	8.81 (3.47)	3.48 (1.37)
1/79	4.80 (1.89)	9.86 (3.88)	5.05 (1.99)
2/79	4.45 (1.75)	5.94 (2.34)	1.50 (0.59)
3/79	6.48 (2.55)	4.09 (1.61)	-2.39 (-0.94)
4/79	6.91 (2.72)	6.32 (2.49)	-0.58 (-0.23)
5/79	7.75 (3.05)	6.99 (2.75)	-0.76 (-0.30)
6/79	7.65 (3.01)	5.79 (2.28)	-1.85 (-0.73)
7/79	8.23 (3.24)	7.72 (3.04)	-0.51 (-0.20)
8/79	7.29 (2.87)	9.25 (3.64)	1.96 (0.77)
TOTAL	78.60 (30.94)	83.52 (32.88)	4.94 (1.94)

[a] Measurements in cm (in)

Glacial material has been deposited over the bedrock in the region. The glacial history of the area is complex for two reasons. First, the depositional environments have changed rapidly with time and have experienced rapid lateral shifts. Secondly, successive glacial stages generally destroyed a large part of the evidence of preceding stages, both glacial and interglacial.

The depositional sequence near the site includes lake bottom sediments in the valley, a delta or coalescing deltas from the side valley and finally a cover of till (see Figure 51). Deltaic deposits are essentially absent at the landfill although several small pockets of well-sorted (compared to the till) water-laid deposits are evident. Deltaic deposits occur very near the site.

The occurrence of two till layers overlying the deltaic deposits, similar in appearance to those at the landfill, indicates that the depositional sequence is complex. Since the glacial action that deposited the till did not destroy this particular deltaic wedge, it can be assumed that the delta was pro-glacial and that the till is a stagnant ice ablation till. Glacial tills generally exhibit low permeability because of the poor coefficient of sorting. However, deltaic wedges are generally good aquifers.

Soils at the permitted sanitary landfill were mapped by the USDA Soil Conservation Service prior to filling operations. The original soils at the landfill were excavated and used during site preparation; the landfill lies on glacial till.

The predominant soils in the vicinity of the landfill were formed from glacial outwash and till consisting of a mixture of sandstone, shale, and limestone. The outwash-derived soil is found to the south and the till-derived soil, to north, east and west. There are six main soils found in this area that are derived from outwash. Chenango and Tioga gravelly silt loams are found on gentle slopes. Palmyra and Howard gravelly loams are found on moderately sloping to very steep slopes. Lordstown channery silt loam, which is derived from till, is found on gently to moderately sloping areas and has shale and sandstone bedrock outcrops. Woostern gravelly loam is found on steep slopes. All these soils are well drained and have moderate to rapid permeability.

Landfill Operations

The permitted sanitary landfill site comprises a landfill, located north of an access road, and a bulky waste fill, located south of the road. The landfill operated between 1971 and 1975 on an 8 hr/day, 5 day/wk, 52 wk/yr schedule; the bulky waste fill opened in 1971 and is still in operation.

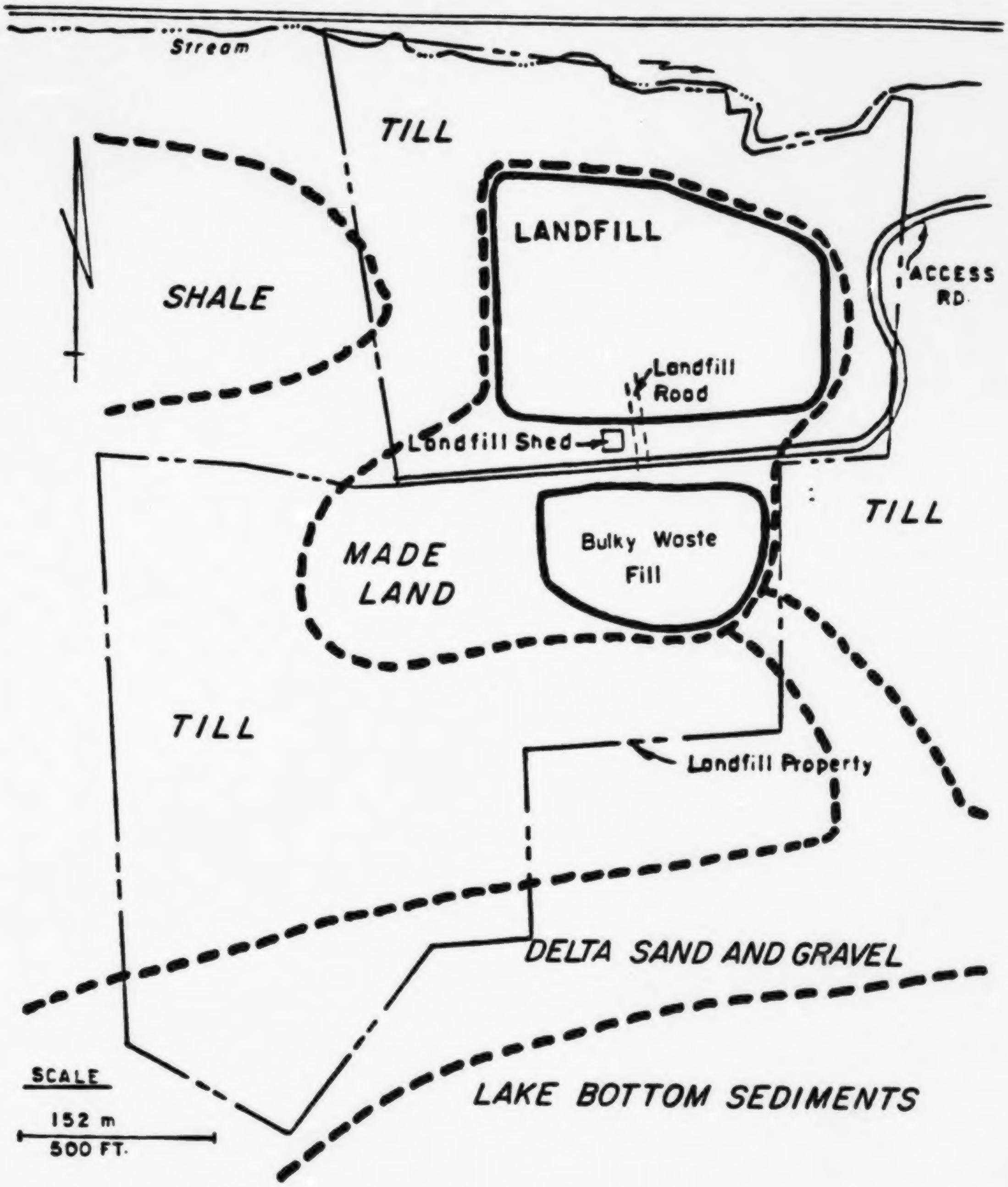

Stream
TILL
LANDFILL
SHALE
ACCESS RD.
Landfill Road
Landfill Shed
TILL
MADE LAND
Bulky Waste Fill
TILL
Landfill Property
DELTA SAND AND GRAVEL
LAKE BOTTOM SEDIMENTS
SCALE
152 m
500 FT.

Figure 51. Map of surficial geology at the permitted sanitary landfill site.

The site served a population of 17,400 and accepted approximately 86 m^3 (112 yd^3) per day of municipal and demolition wastes while the landfill was operating.

Approximately 4 of the 20 ha (10 of the 50 ac) available are occupied by the landfill which used the trench method. Trenches, varying in depth from 3 to 6 m (9-20 ft), were developed in the glacial till which overlies the shale bedrock. As a trench was excavated, the sediment (glacial till) removed was stockpiled next to the trench and was then used for cover material as the refuse was emplaced; final cover was 0.6 m (2 ft) deep. The site is sparsely vegetated with grasses and shrubs. White goods and tires were segregated and stored. The landfill received a total of 38,800 tonnes (42,750 tons) of municipal refuse. The calculated density of this material is 386 kg/m^3 (652 lb/yd^3). The average volume per unit area is 25,155 m^3/ha (13,104 yd^3/ac).

The bulky and non-putrescible waste site located south of the landfill occupies 1.6 ha (4 ac). There is some evidence that the bulky waste site received small quantities of municipal refuse near the time of the study period. The site is periodically covered.

Monitoring Network

Monitoring points were located in order to obtain samples of upgradient ground water, ground water under the landfill, ground water downgradient from the landfill, and surface water near the landfill. Six monitoring wells drilled during studies conducted in 1975 and 1977 were used in this study and were designated as MP #1 through #6 (see Figure 52, Table 14, and Appendix A). All these wells were drilled using an air-rotary drilling rig and were cased with 15.88 cm (6.25 in) steel casing.

MP #1, in the bulky waste area, encountered glacial till and minor thin lenses of relatively fine water-laid deposits to a depth of 16.5 m (54.0 ft). From 16.5 to 20.0 m (54.0-66.0 ft), grey, weathered bedrock was encountered. The well was cased to 17.8 m (58.4 ft) and the lowermost 6.1 m (20.0 ft) of casing was torch-slotted.

In MP #2, drilled adjacent to the east side of the landfill, there was glacial till to 15.5 m (51.0 ft). Bedrock was encountered from 15.5 m (51.0 ft) to 30.5 m (100.0 ft) with the degree of weathering diminishing to essentially unweathered rock by 21.0 m (68.0 ft). The hole was cased to 20.7 m (67.8 ft) with the lowermost 9.2 m (30.0 ft) being torch-slotted. This well was located in the dominant downgradient direction of ground-water movement.

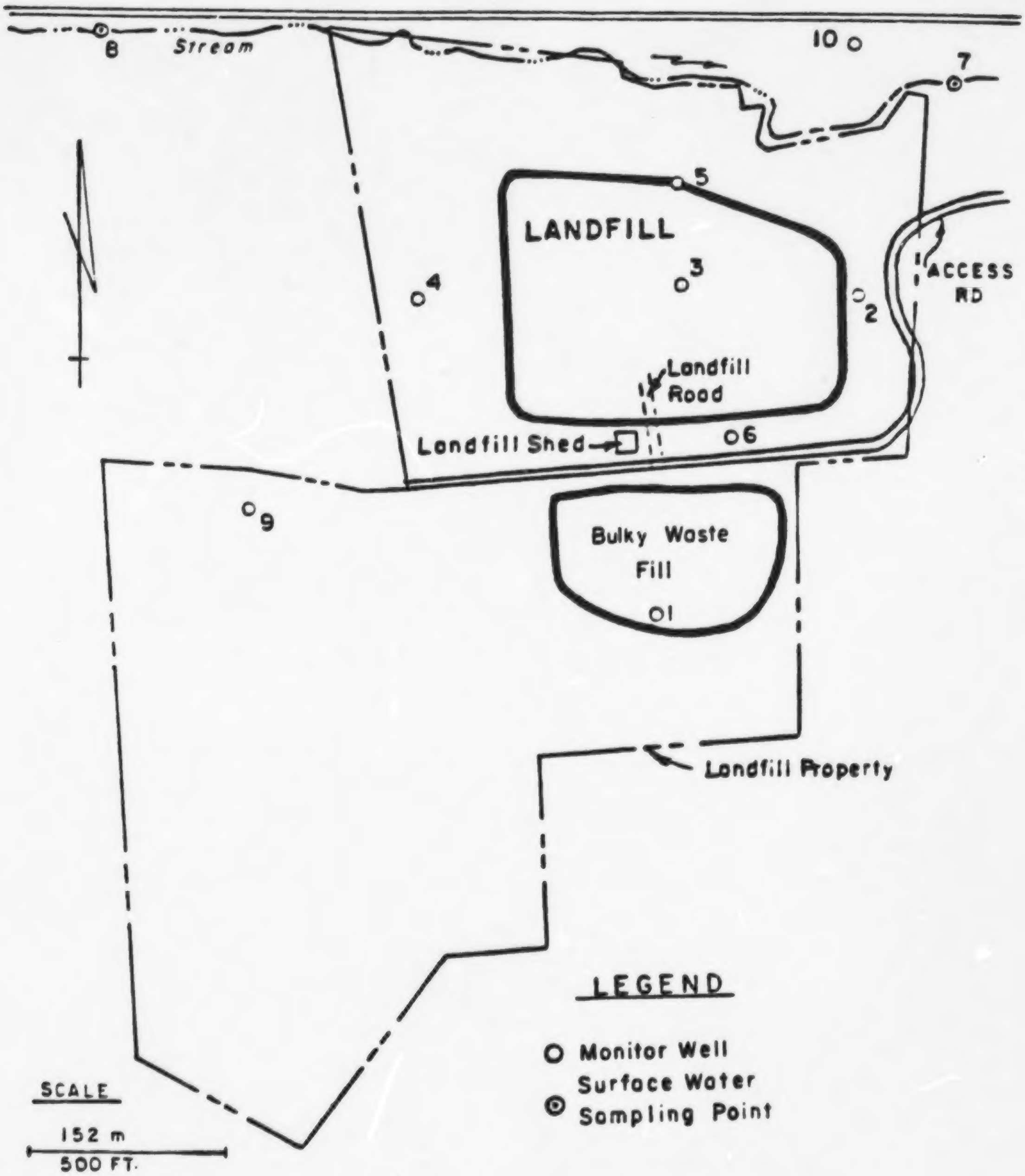

8
Stream
10
7
5
LANDFILL
3
4
2
ACCESS RD
Landfill Road
Landfill Shed
6
9
Bulky Waste Fill
1
Landfill Property
LEGEND
Monitor Well
Surface Water Sampling Point
SCALE
152 m
500 FT.

Figure 52. Location of monitoring points of the permitted sanitary landfill site.

TABLE 14. MONITOR WELL CONSTRUCTION DETAILS - PERMITTED SANITARY LANDFILL[a]

MP #	Well depth	Total[b] casing	Type casing	Section slotted	Elevation[c] top of casing	Reference[d]	Surface elevation
1	20.1 (66.0)	19.2 (62.8)	15.88 cm (6.25 in.) Steel	17.8-11.7 (58.4-38.4)	333.94 (1,095.60)	1.34 (4.40)	332.60 (1,091.20)
2	30.5 (100.0)	21.0 (68.9)	15.88 cm (6.25 in.) Steel	20.7-11.5 (67.8-37.8)	339.07 (1,112.45)	0.34 (1.12)	338.73 (1,111.33)
3	19.2 (63.0)	8.2 (27.0)	15.88 cm (6.25 in.) Steel	Open Hole	342.15 (1,122.55)	0.78 (2.58)	341.37 (1,119.97)
4	31.1 (102.0)	3.0 (9.8)	15.88 cm (6.25 in.) Steel	Open Hole	349.26 (1,145.85)	0.40 (1.30)	348.86 (1,144.55)
5	31.1 (102.0)	15.2 (50.0)	15.88 cm (6.25 in.) Steel	Open Hole	340.00 (1,115.50)	0.30 (0.98)	339.70 (1,114.52)
6	20.7 (68.0)	21.3 (69.8)	15.88 cm (6.25 in.)	20.7-14.3 (68.0-47.0)	338.24 (1,109.70)	0.54 (1.75)	337.70 (1,107.95)

[a] Measurements in meters (feet) unless otherwise indicated.
[b] Total casing is equal to the casing in the ground plus casing above ground (Reference).
[c] All elevations relative to mean sea level.
[d] Reference above ground surface from which water level measurements are taken.

MP #3 was drilled through a refuse trench in the center of the landfill. The first 1.2 m (4.0 ft) were refuse with thin cover. Glacial till was encountered from 1.2 to 6.1 m (4.0-20.0 ft). From 6.1 to 19.2 m (20.0-63.0 ft), grey shale bedrock was encountered. The hole was cased to approximately 7.4 m (24.4 ft) and grouted. This well was drilled to determine water quality below the landfill.

MP #4, the background well, was drilled on a rise to the west of the landfill. It penetrated 1.1 m (3.5 ft) of glacial till and grey shale from 1.1 to 31.1 m (3.5-102.0 ft); 30 m (9.8 ft) of casing was grouted in the hole.

MP #5, a downgradient well located on the north edge of the landfill, penetrated 0.6 m (2.0 ft) of cover material, fill from 0.6 to 0.8 m (2.0-2.5 ft), till from 0.8 to 13.3 m (2.5-43.5 ft) and grey shale from 13.3 to 31.1 m (43.5-102.0 ft); 15.2 m (50.0 ft) of casing was surface-grouted in the hole.

MP #6 was drilled through 19.2 m (63.0 ft) of till and grey shale from 19.2 to 20.7 m (63.0-68.0 ft). The entire depth of the well was cased and torch-slotted from 14.3 to 20.7 m (47.0-68.0 ft). This well was drilled between the landfill and the bulky waste fill to determine their relative impact on ground water.

MP #7 was the surface water sampling point downstream of the landfill and MP #8 was the upstream surface water sampling point.

Historical data was obtained about these eight monitoring points and, in addition, about MP #9, a dug well upgradient of the bulky waste fill, and MP #10, a domestic water supply well located approximately 125 m (410 ft) northeast of the landfill. Neither well log data nor construction details were available for MP #9 or #10.

Particle Size Analyses

Three samples obtained during the drilling of MP #6 were analyzed for particle size distribution to better determine the attenuation characteristics of the geologic material (see Table 15 and Appendix B). The samples are glacial till and have increasing percentages of coarse fragments and decreasing percentages of clay and silt with increasing depth. There is a small amount of clay present; therefore, some adsorption of ions from leachate occurs with the matrix material.

TABLE 15. PERCENTAGE OF SEPARATES BY WEIGHT FOR THE GEOLOGIC MATERIALS AT THE PERMITTED SANITARY LANDFILL.[a]

Sample description	% Clay	% Silt	% Sand	% Coarse fragments
MP #6 Glacial Till 0.3 - 1.5 m (1.0 - 5.0 ft)	12	21	24.5	42.5
MP #6 Glacial Till 3.0 - 6.1 m (10.0 - 20.0 ft)	8	12	30	50
MP #6 Glacial Till 7.6 - 10.7 m (25.0 - 35.0 ft)	7	12	26	55

---

[a] Size limits for the soil separates are based on the U. S. Department of Agriculture system. The diameter range for separates is:

Clay, less than 0.002 mm
Silt, 0.002 - 0.05 mm
Sand, 0.05 - 2.0 mm
Coarse Fragments, greater than 2.0 mm

Hydrogeology of the Permitted Sanitary Landfill Site

The permitted sanitary landfill is situated on a topographic divide between a creek and an unnamed tributary of the creek. The site is underlaid by a wedge of gravelly clay till which overlies shale bedrock. Because of the topographic divide, ground water flows to the north and southeast, discharging to the two creeks. In the glacial deposits, ground water occurs under water table conditions; its movement through the shale is minimal and is dependent on flow through fractures and bedding planes.

The water budget for the permitted sanitary landfill is based on long-term stream gaging records for the creek downstream of the landfill, precipitation records from a nearby weather station, and computed actual evapotranspiration. Analysis of the stream-gaging records indicated that total runoff is 30 percent of the average annual 78.60 cm (30.94 in) precipitation (PPT). On the basis of regional studies, the USGS estimates that ground-water recharge (GW) is 75 percent of runoff; the remaining surplus is surface water (SW). Computed actual evapotranspiration (ET) represents 70 percent of precipitation. The water budget can therefore be expressed as:

$$\begin{array}{ccccccc} \text{PPT} & = & \text{ET} & + & \text{SW} & + & \text{GW} \\ 78.60\text{ cm} & = & 55.02\text{ cm} & + & 5.90\text{ cm} & + & 17.68\text{ cm} \\ (30.94\text{ in}) & = & (21.66\text{ in}) & + & (2.32\text{ in}) & + & (6.96\text{ in}) \end{array}$$

The landfill was constructed on a 4-ha (10-ac) base consisting of glacial till. Leachate generation by the sanitary landfill can be estimated using the water budget and the area of the landfill base. Multiplying the 17.68 cm (6.96 in) of annual infiltration by the 4-ha (10-ac) base yields 7,072 m^3 (5.80 ac-ft) of potential leachate generation.

Figure 53 shows a cross section of the permitted sanitary landfill taken along line AA' (shown on Figure 54) and passing from north to south through the stream, MP #5, MP #3, and MP #1. The landfill and the bulky-waste fill were constructed on bases of glacial till which varies in thickness from 5 to 20 m (16-66 ft). The till overlies the low-permeability shale bedrock; the irregular contact between the two units is a result of glacial action.

The water table gradient in the study area follows the topography of the site as shown on the water table map, Figure 55; a ground-water divide runs through the site. Ground water for most of the landfill flows to the north and discharges into the creek; the remainder flows to the south and east toward a tributary of the creek. Depth to the water table varied (see Appendix C) from 4.30 to 22.46 m

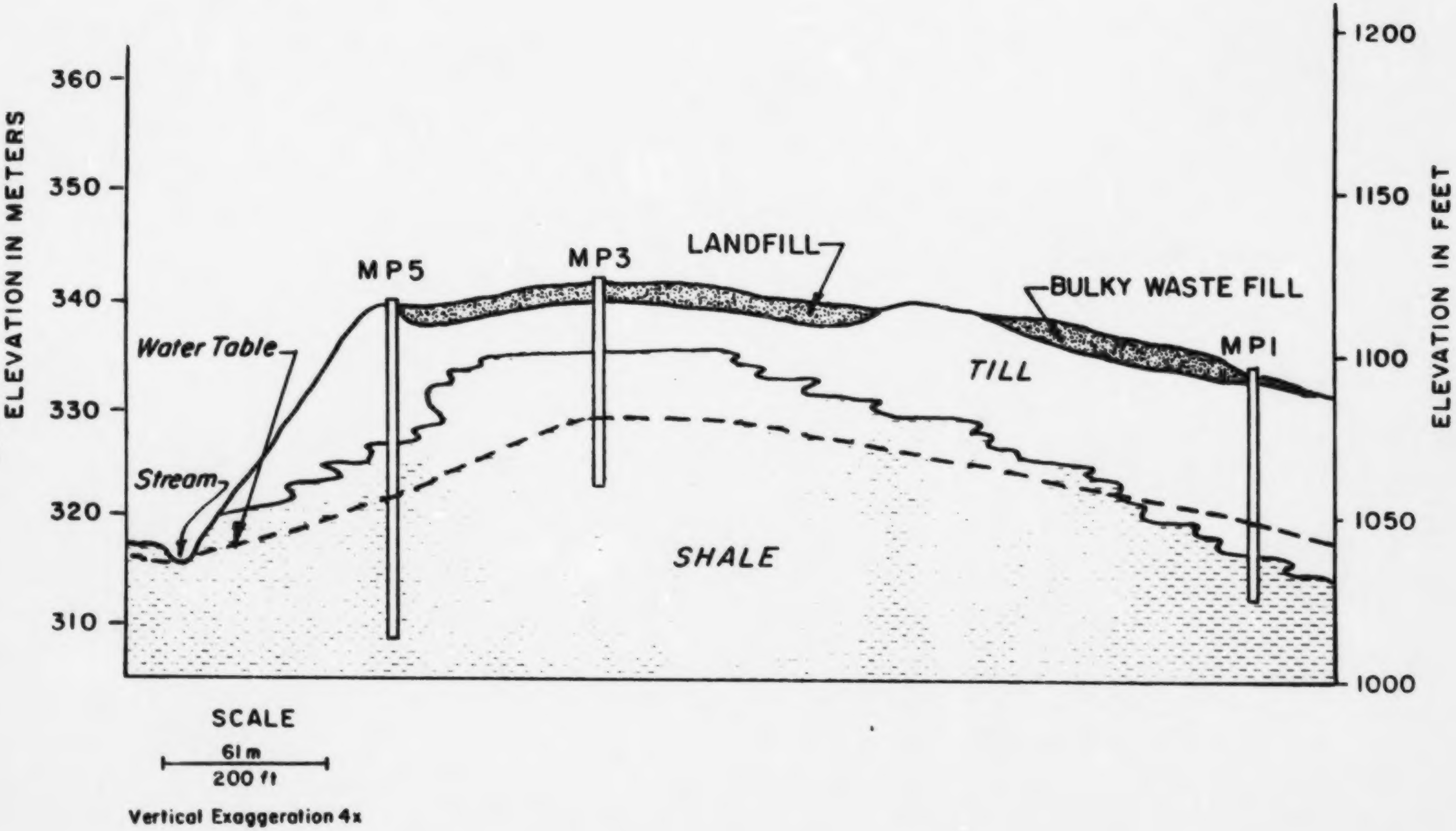

ELEVATION IN METERS
360
350
340
330
320
310
ELEVATION IN FEET
1200
1150
1100
1050
1000
MP5
MP3
LANDFILL
BULKY WASTE FILL
MP1
Water Table
TILL
Stream
SHALE
SCALE
61 m
200 ft
Vertical Exaggeration 4x

Figure 53. Cross section of the permitted sanitary landfill site.

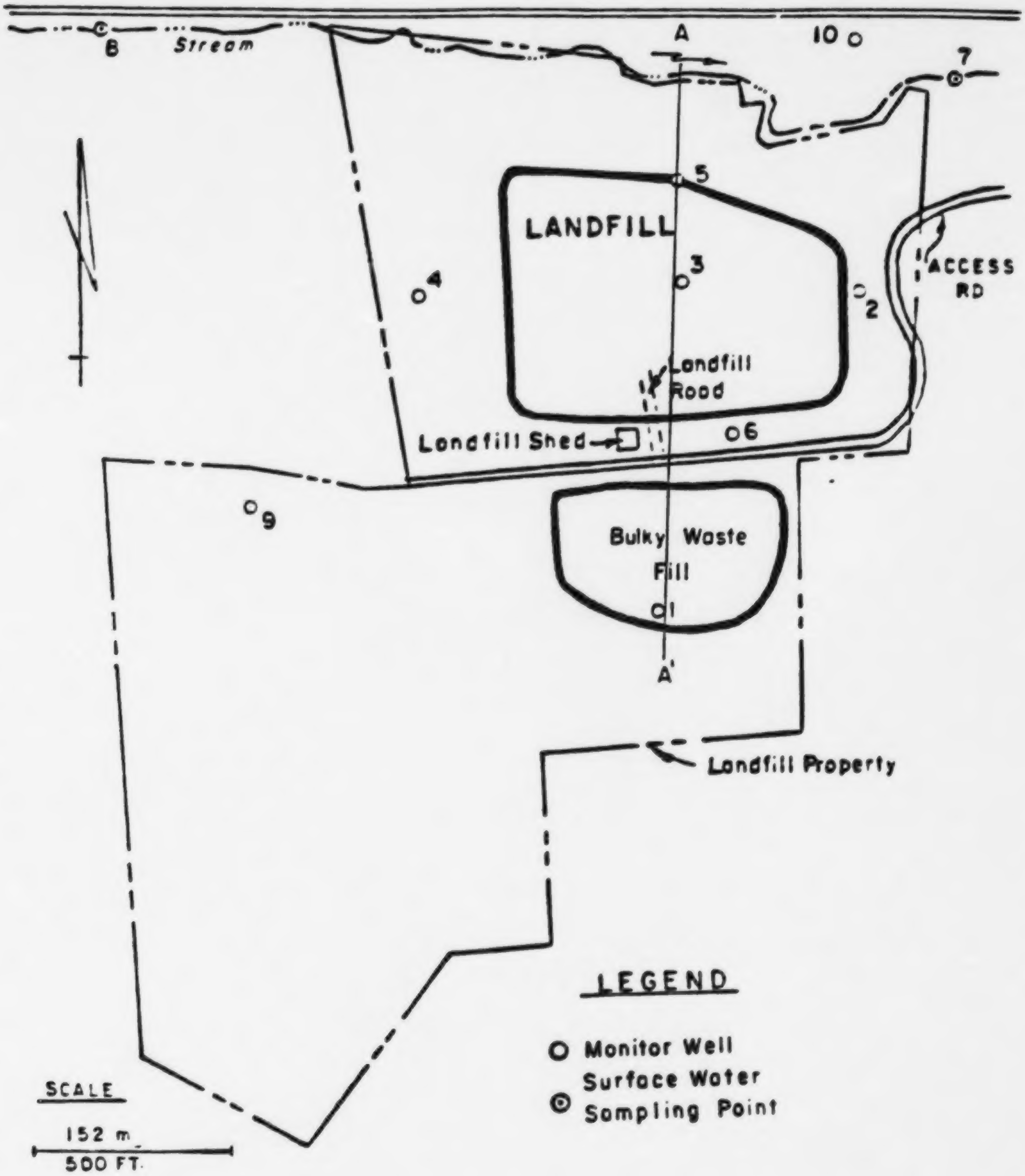

A
10
7
8
Stream
5
LANDFILL
3
4
2
ACCESS RD
Landfill Road
Landfill Shed
6
9
Bulky Waste Fill
1
A'
Landfill Property
LEGEND
Monitor Well
Surface Water Sampling Point
SCALE
152 m
500 FT.

Figure 54. Map showing the location of the line of cross section, AA'.

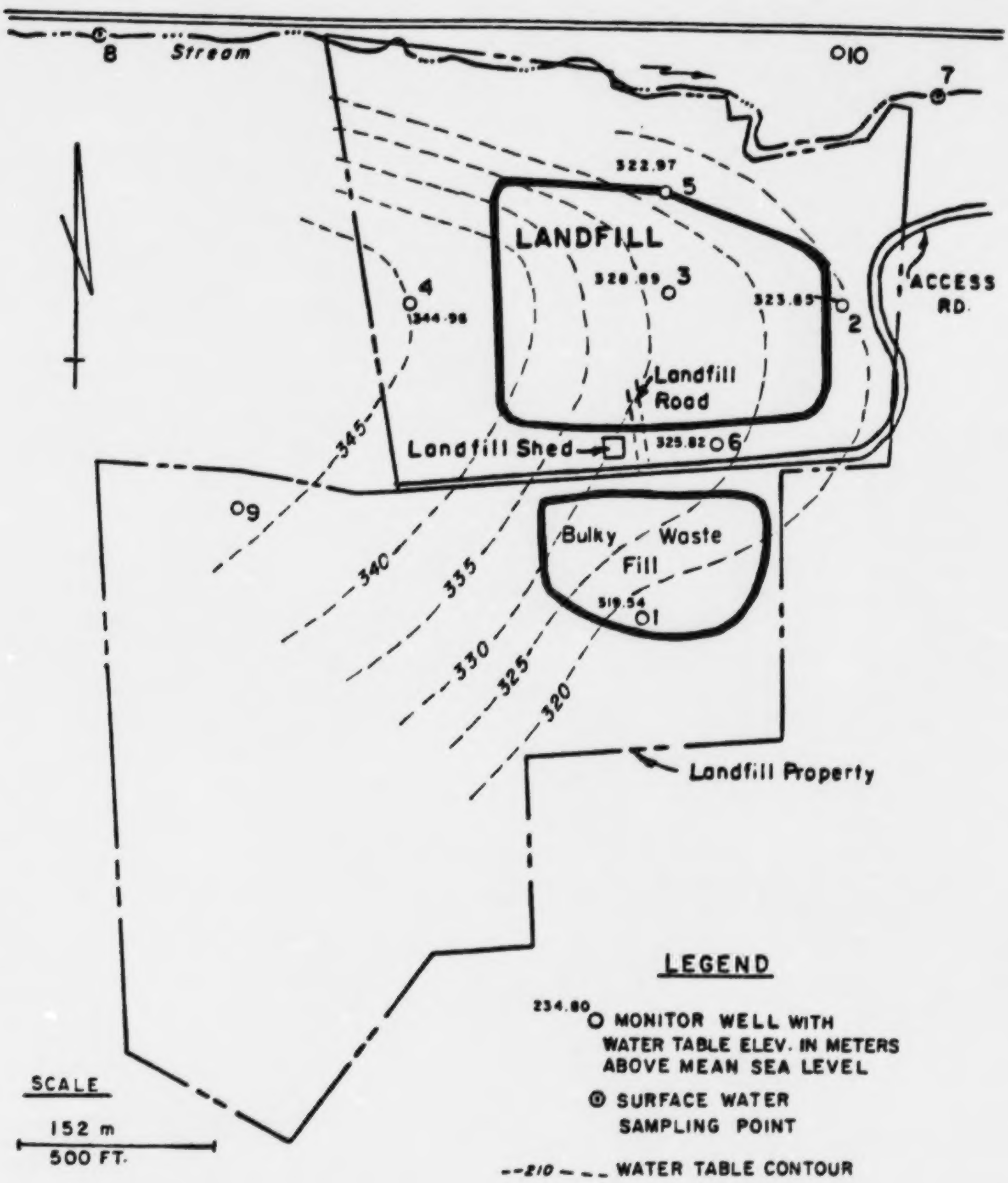

8
Stream
10
7
322.97
5
LANDFILL
328.89
3
4
344.96
323.85
2
ACCESS RD.
Landfill Road
Landfill Shed
325.82
6
345
9
Bulky Waste Fill
319.54
1
340
335
330
325
320
Landfill Property
LEGEND
234.80 MONITOR WELL WITH WATER TABLE ELEV. IN METERS ABOVE MEAN SEA LEVEL
SURFACE WATER SAMPLING POINT
210 WATER TABLE CONTOUR
SCALE
152 m
500 FT.

Figure 55. Map of water table at the permitted sanitary landfill site.

(14.10-73.70 ft); the seasonal fluctuation in the water table ranged from 0.12 to 5.43 m (0.39-17.81 ft).

As precipitation infiltrates through the landfill, leachate is produced. After leaving the landfill, it percolates through the till under unsaturated conditions; ion exchange occurs on the surface of clay particles and clay lenses in the till. The leachate eventually enters the ground-water flow system and is diluted. Due to the low velocity of ground water in the area, dispersion is minimal and contamination remains localized.

Water Chemistry at the Permitted Sanitary Landfill Site

Bar graphs of the mean concentrations of alkalinity, acidity, TDS, TKN, COD, and TOC were constructed for all monitoring points (see Figure 56, 57, and 58, Section 2 and Appendix E). The mean values for each sampling point, except MP #7, were calculated using data from four sampling rounds. On December 6, 1978 an analytical error produced erroneous values for alkalinity, acidity, sulfate, and total solids at MP #7. Therefore, the mean values for these parameters have been recalculated using data from the three remaining sampling dates.

The background well (MP #4) had a mean value for alkalinity of 231.3 mg/l. Four of the six ground-water sampling points (MP #1, #2, #3, and #5) showed mean values for alkalinity higher than those seen in the background well (MP #4). In descending order of concentration, MP #2 has the highest mean value (581.0 mg/l) followed by MP #1 (440.3 mg/l), MP #3 (346.0 mg/l), and MP #5 (279.0 mg/l). The remaining downgradient well (MP #6, 173.0 mg/l) and the surface water sampling points (MP #7, 134.0 mg/l and MP #8, 120.0 mg/l) showed mean values for alkalinity that were lower than that found at the background well (MP #4).

Mean values for acidity for each of the sampling points are displayed in Figure 56 which shows that the relationships among the monitoring points are similar for acidity to those noted for alkalinity. The background well (MP #4) showed a mean value for acidity of -247 mg/l. MP #2 showed the most negative value for acidity (-616 mg/l) followed by MP #1 (-466 mg/l), MP #3 (-381 mg/l), and MP #5 (-260 mg/l). MP #6 had a mean value of -180 mg/l for acidity and the two surface water sampling points (MP #7 and #8) showed mean values of -139 mg/l and -189 mg/l, respectively.

Figure 57 displays mean values for TDS concentrations. All sampling points, except the two surface water monitoring points (MP #7 and #8), show mean values for TDS higher than those of the background well (MP #4, 248 mg/l). MP #3 had

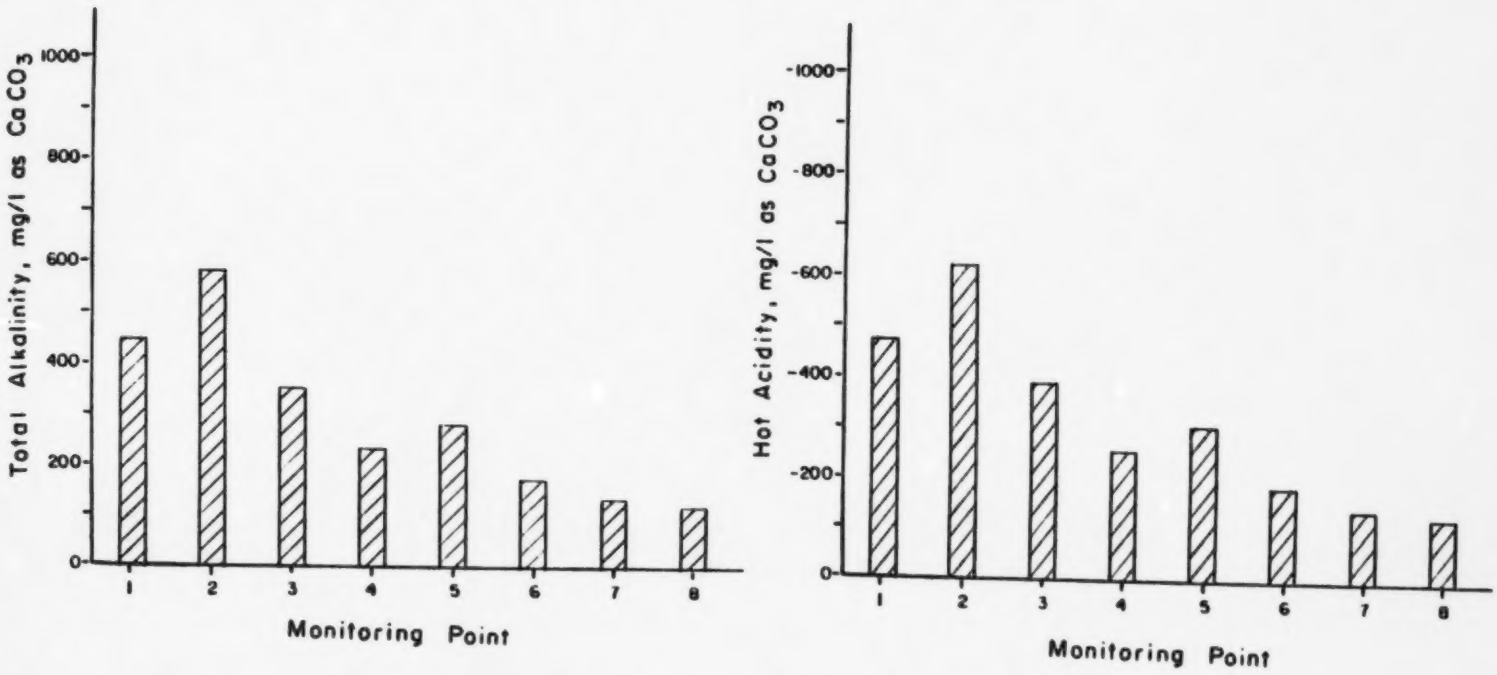


Figure 56. Bar graphs for alkalinity and acidity at the permitted sanitary landfill site.

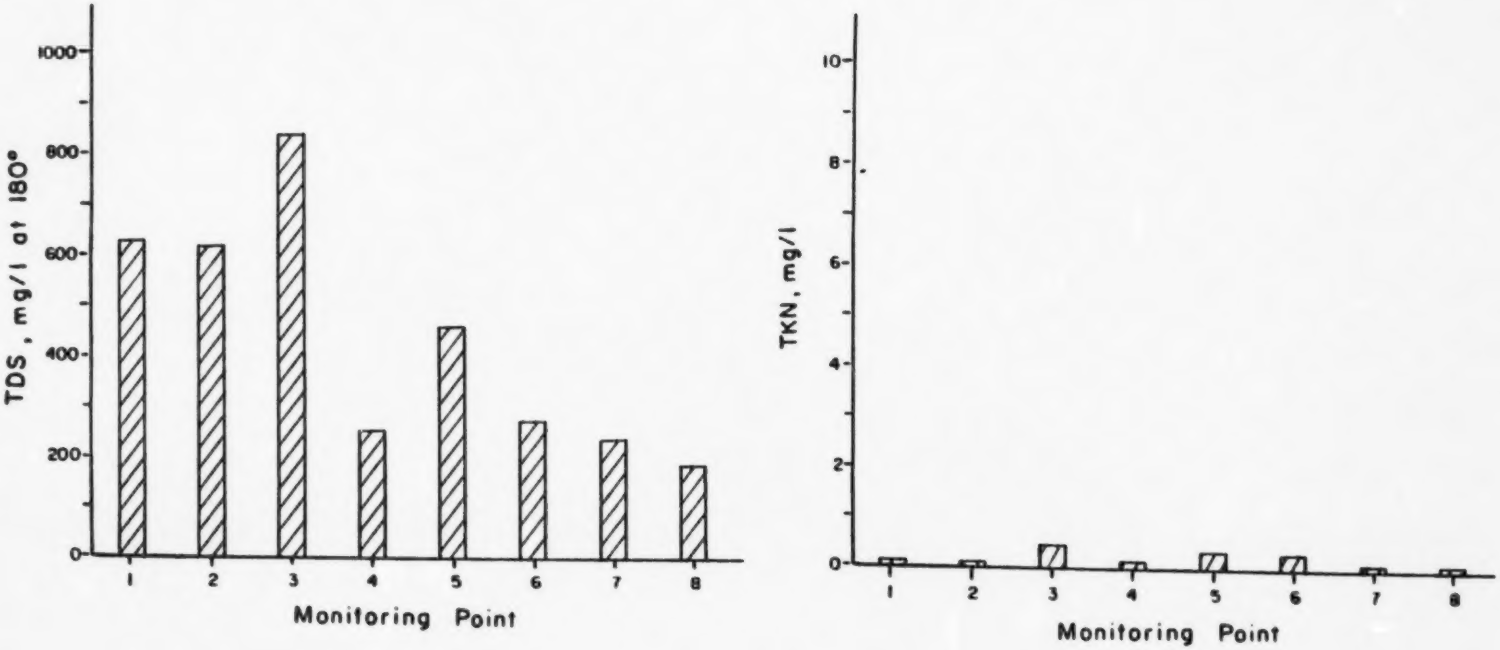


Figure 57. Bar graphs for TDS and TKN at the permitted sanitary landfill site.

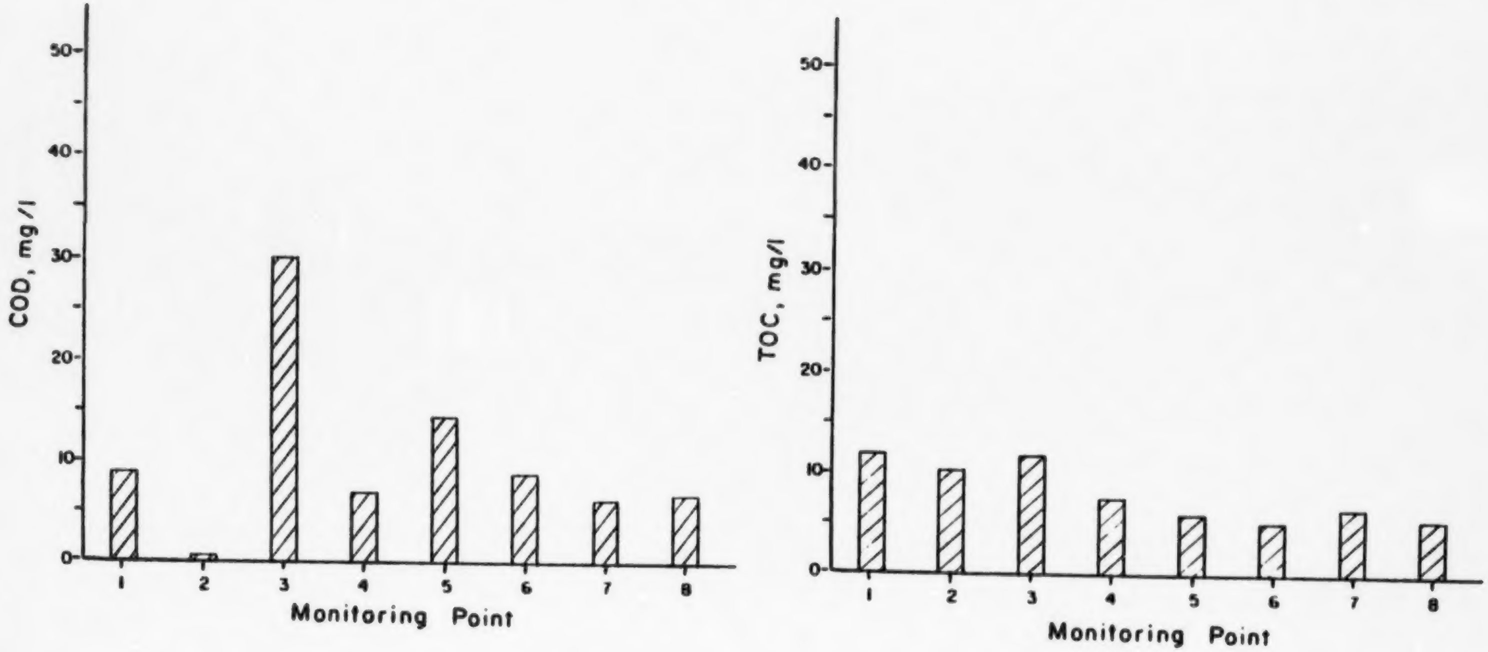


Figure 58. Bar graphs for COD and TOC at the permitted sanitary landfill site.

the highest mean concentration (827 mg/l), and, in declining order, MP #1 (617 mg/l), MP #2 (607 mg/l), MP #5 (455 mg/l) and MP #6 (273 mg/l). MP #7 (downstream) showed a mean TDS concentration of 232 mg/l and MP #8 (upstream) had 182 mg/l.

The mean values for TKN (see Figure 57) were less than 1.00 mg/l at all of the monitoring points. The bar graph of these mean values shows that the difference in TKN among the monitoring points is small. However, MP #3, #5, and #6 were elevated above MP #4 while MP #2 showed the lowest TKN value among the wells.

Mean values for COD (see Figure 58) show quite different relationships between monitoring points from those seen in alkalinity, acidity, and TDS. The background well (MP #4) showed a mean value of 6.75 mg/l of COD. MP #3 (29.90 mg/l), MP #5 (14.33 mg/l), MP #1 (9.00 mg/l), and MP #6 (8.78 mg/l) all exhibit values for COD that are higher than those of the background well. MP #2 showed the lowest mean value for COD (0.55 mg/l). The two surface water sampling points (MP #7 and #8) had mean values for COD that were below those of MP #4, the background well. MP #7 had a mean COD of 5.95 mg/l and the upstream sampling point (MP #8) gave a mean value of 6.52 mg/l for this parameter.

Mean values for TOC at each sampling point are displayed in Figure 58 which shows that MP #1, #3, and #2 all have mean values that are higher than that for the background well (MP #4) which exhibited a mean TOC value of 7.1 mg/l. MP #1 and #3 had nearly equivalent mean TOC concentrations with values of 11.8 mg/l and 11.7 mg/l, respectively. MP #2 had a mean value of 10.1 mg/l. MP #5 and #6 and the stream sampling points (MP #7 and #8) exhibited mean TOC concentrations that were lower than that of the background well. MP #7 had a TOC mean value of 6.2 mg/l and MP #5 of 5.9 mg/l. MP #8 gave a mean value of 5.3 mg/l and the lowest mean TOC concentration was seen at MP #6 (5.1 mg/l).

Overall, the bar graphs demonstrate that contamination of ground water is confined to the area immediately beneath and surrounding the landfill. This is particularly clear at MP #1, #2, #3, and #5. Two parameters (COD and TKN) might seem to provide exceptions to this observation. However, since COD is a measurement of the amount of chemical material that has yet to be oxidized, a low mean value for COD at MP #2 indicates advanced leachate degradation at this sampling point. This observation is supported by high nitrate and low ammonia concentrations (see Appendix E).

The bar graphs also illustrate that surface water quality in the adjacent stream has been relatively unaffected by the presence of the landfill. While some of the parameters (alkalinity for example) increase in a downstream direction, others (such as COD) decrease in the same direction. Furthermore, the magnitude of the changes between MP #8 and #7 is such that they are insignificant. Attributing these changes solely to the presence of the landfill would be speculative and would ignore ecological and hydrological factors that also affect these parameters.

In order to provide further insight into the effect of the landfill on water quality in the area, Stiff diagrams were constructed (see Figure 59). Background concentrations of ionic species in ground water are represented by MP #4. The ionic composition of ground water underlying the landfill is characterized by the diagram for MP #3. By comparing the shapes of these plots with those of the downgradient wells, it is evident, particularly with reference to the higher sodium and chloride concentrations, that MP #5 is contaminated by leachate. The diagram for MP #6 resembles that for MP #3 more than it does the diagram for MP #4, indicating that this well has been affected by leachate also. MP #2 has a Stiff diagram that resembles that of MP #4 (background) more than any other diagram. However, MP #2 shows some ionic species (zinc and nitrate, for example) to be present in higher concentrations than at MP #4 indicating that MP #2 has been contacted by leachate.

The Stiff diagram for MP #1 has a distinctive shape showing high concentrations of cations. This may be expected because of the nature of the materials deposited within the bulky fill area. The elevated level of iron, for example, may be directly attributed to the presence of metal objects within the bulky fill. The fact that the diagrams for the surface water sampling points (MP #7 and #8) are almost identical to each other reaffirms the earlier observation that the landfill area has had no impact on the stream.

To delineate oxidizing and reducing environments, nitrogen ratios were calculated (see Figure 60). The larger ratio values for MP #3 and #6 (6.62 and 9.67, respectively) show that these monitoring points are under moderately reducing conditions. The ratio for MP #5 (3.81) also shows evidence of a slightly reducing environment. While the ratio for MP #5 represents a reducing environment, it also shows that MP #5 has less of a reducing character than either MP #6 or #3.

The ratio value of 0.16 indicates that MP #4 (background) has an oxidizing character. Similarly, MP #2 (0.07) and MP #1 (0.76) can be designated as oxidizing environments. The two surface water sampling points (MP #7 and #8) also

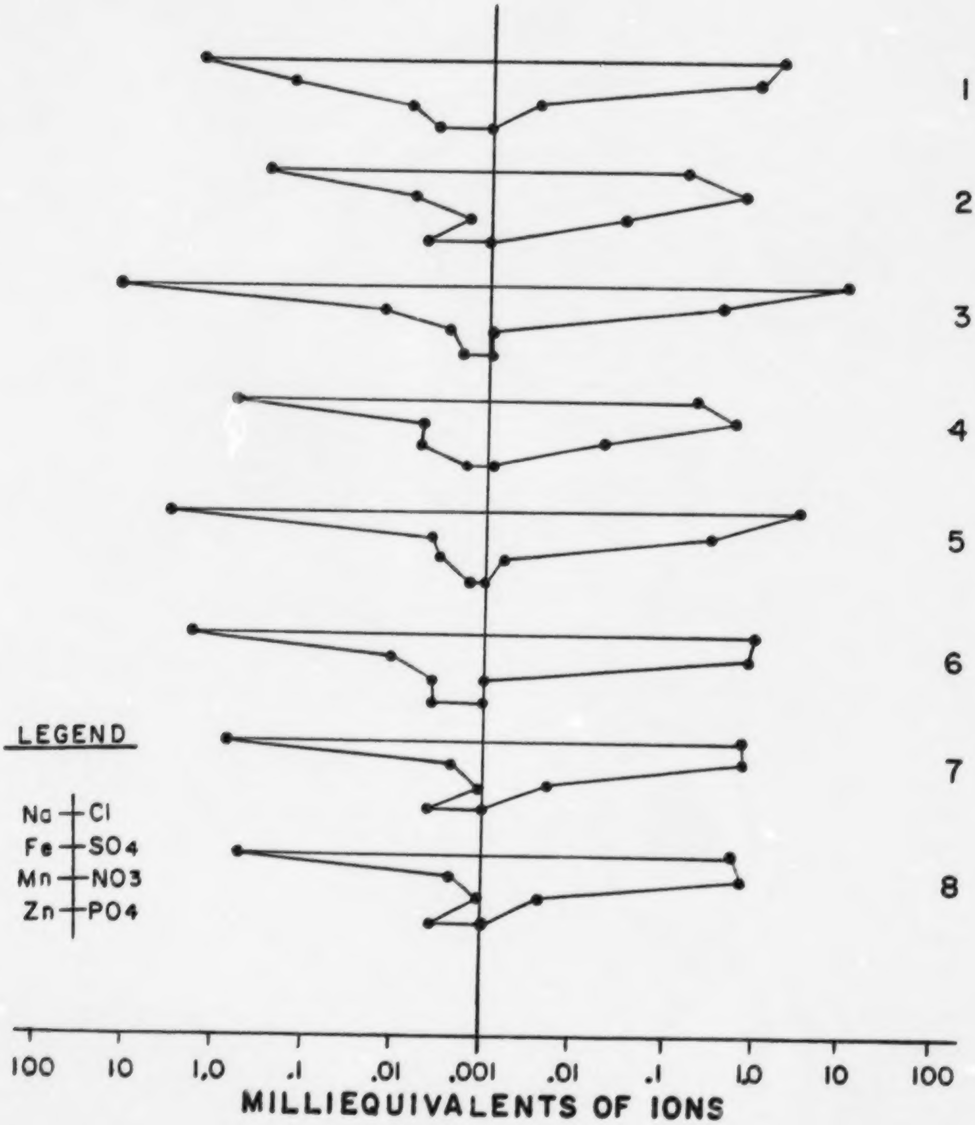


Figure 59. Modified stiff diagrams showing results of chemical analyses at the permitted sanitary landfill site.

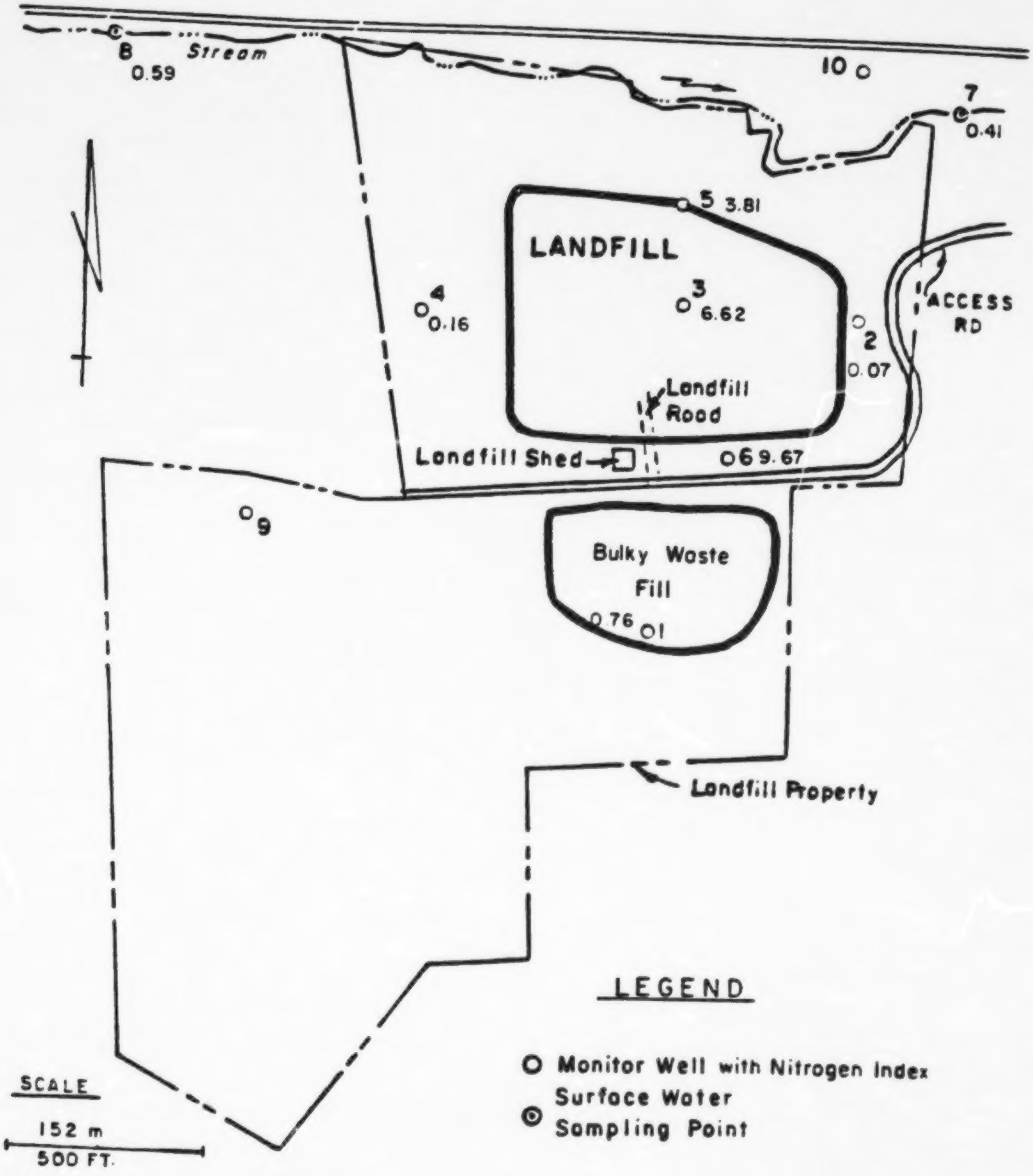

8
0.59
Stream
10
7
0.41
5
3.81
LANDFILL
4
0.16
3
6.62
2
0.07
ACCESS RD
Landfill Road
Landfill Shed
6 9.67
9
Bulky Waste Fill
0.76
1
Landfill Property
LEGEND
Monitor Well with Nitrogen Index
Surface Water Sampling Point
SCALE
152 m
500 FT.

Figure 60. Nitrogen index showing the ratio of organic nitrogen plus ammonia nitrogen (TKN) to nitrite plus nitrate nitrogen ($NO_2 + NO_3$).

have low ratio values. MP #8 (upstream) has a ratio value of 0.59 and MP #7 (downstream) gives a ratio value of 0.41.

The relatively higher ratio values for MP #6 and #3 show that the more reducing environments are restricted to the central and southeastern portions of the landfill. The intermediate ratio value for MP #5 is attributable to a combination of location in relation to the landfill and position within the ground-water flow system.

The low ratio at MP #2, stemming from low TKN and high nitrate values, is a reflection of an advanced degree of degradation. The same phenomenon was noted earlier when MP #2 exhibited a low mean value for COD. The low value for MP #1 is a reflection of the fact that the materials in the bulky waste fill are relatively inorganic in nature.

The low ratio values for MP #7 and #8 show that the chemical environment within the stream is an oxidizing one. This data confirms the earlier contention that the landfill has had no adverse effect on the stream.

In order to document any changes in water quality through time, historical data (see Appendix D) was evaluated and compared with data collected during the present study. A sufficient number of analytical results exist to allow the identification of trends, or their absence, within COD, specific conductance, and concentrations of particular cations and anions.

Both the historical data and data from the present study demonstrate that the fluctuation within COD is seasonal. Thus, COD values are highest during the summer and lowest during winter. Yet, even considering these seasonal fluctuations, the values for this parameter clearly point to a decrease in COD in all the downgradient wells (MP #2, #5, and #6) through time. MP #3, however, shows a slight increase in COD attributable to the continual breakdown of material within the landfill.

Unlike COD, specific conductance for nearly all the monitoring points remains relatively constant through time. MP #3, however, shows an increase in specific conductance. Again, this trend is a reflection of the continued breakdown of materials within the landfill.

Data for sodium shows that this cation increases in concentration with time at MP #1, #2, and #3. During the period when the historical data was being collected, analysis for sodium was peformed only sporadically for the other monitoring points and therefore is of little value. Therefore, zinc shows increases in concentration for all wells except

MP #3. Typically, cations like sodium and zinc are not very mobile and are bound up on the cationic exchange complex. Therefore, the increase in sodium and zinc demonstrates that attenuation via the exchange complex is minimal. Manganese, iron, and copper show decreases in concentrations at all wells.

Nitrate shows a decrease in concentration at all points with time except at MP #2 where the concentration of nitrate increases. As indicated previously, this is due to the accumulation of this species as a result of advanced degradation.

In conclusion, comparing the historical data with that of the present study demonstrates that the impact of the landfill on ground and surface water in the area of the landfill is diminishing with time. MP #3, however, shows little evidence of improvement. This is attributable to the location of this monitoring point within the landfill and it may be expected that this well would show a slower rate of improvement. MP #7 and #8 have historical concentration values for the parameters studied that are consistent with those of the present study. The lack of change and the low magnitude of the parameter concentrations show that the landfill is not degrading water quality within the adjacent stream.

In summary, all of the water quality indicators examined show that the landfill has had a localized and moderate effect on ground water. Since ground water comprises a major portion of the stream's discharge, data collected from MP #7 and #8 offers support for this conclusion. In addition, close agreement of indicator values between the upstream sampling point (MP #8) and the downstream sampling point (MP #7) demonstrates that water quality in the stream is not affected by leachate from the landfill. MP #2, #3, and #5 show the greatest impact from the landfill. Generally, these three wells have indicator values higher than those observed at MP #4. MP #2, however, exhibited the lowest COD found at any of the monitoring points. This fact, in combination with high nitrate, low ammonia and low organic nitrogen levels, points to an advanced degree of degradation of the leachate at this sampling point. This observation is confirmed by a low value for the nitrogen ratio. Moreover, conservative parameters, such as TDS, would not be drastically altered by this phenomenon.

MP #6 shows evidence of a limited amount of contamination by leachate. The considerations indicating this contamination are COD levels, the Stiff diagram, and the nitrogen ratio. Historical data also points to contamination at this sampling point. The remaining parameters analyzed in the present study do not indicate contamination primarily because of the location of MP #6 within a locally complex hydrogeological flow system and the localized effect of the leachate.

Data for MP #1 demonstrates that the bulky waste fill is also a source of leachate. As might be expected, the character of the leachate from this area differs from that produced by the landfill. This difference may be illustrated by comparing the Stiff diagram for MP #1 with that for MP #3 and also by the low value of COD for MP #1.

In conclusion, the historical data and the data from the present study show that the impact of the leachate is localized and is diminishing through time.

SECTION 6

COMPARISON OF THE FIVE ALTERNATIVE SOLID WASTE DISPOSAL METHODS WITH STANDARD SANITARY LANDFILL METHODS

The characteristics associated with each method of landfilling in contrast to the site specific conditions that permit a landfill to pollute or prevent it from doing so are evaluated in this Section. Each special method (hillfilling, balefilling, millfilling, and strip mine landfilling) is compared with the conventional method of sanitary landfilling in an effort to delineate the advantages and/or disadvantages of each. The usefulness and applicability of each landfilling method is considered with reference to a range of geographic locations.

CHARACTERISTICS AFFECTING THE POTENTIAL TO POLLUTE

Each of the methods of landfilling examined in this study has characteristics that permit or, conversely, limit pollution; each type of landfill produces a typical leachate. Strength and trends of leachate vary among the several types of landfills. In addition to the characteristics of each method that produce pollution, there are site-specific characteristics which affect the potential pollution from each landfill. These methodological and site-specific characteristics will be highlighted in this Section and comparisons with landfills employing the same method will be discussed where appropriate. The relative impacts of the five types of landfills on ground and surface water as shown by water quality in representative downgradient wells will also be summarized.

In order to present comparisons among the landfill sites in the clearest and most concise manner, several Tables have been prepared. Table 16A illustrates the age, area, weight of refuse, average volume of refuse per area, refuse density, and cover-to-refuse ratio for each of the five landfills. Table 16B shows pertinent site characteristics of each landfill including the sediment type and average percent clay in the sediment, the depth to water below the landfill base, annual precipitation and its devia-

TABLE 16 A. CHARACTERISTICS CONTRIBUTING TO THE IMPACT OF EACH LANDFILL ON GROUND AND SURFACE WATER

Landfill	Years since completion	Area of fill	Total weight of refuse	Average volume per unit area	Approximate density of refuse	Method of operation and cover to refuse ratio
Hillfill	8 (operated from 1965-71)	16 ha (40 ac)	272,340 tonnes[a] (300,000 tons)	47,500 m^3/ha (25,000 yd^3/ac)	355 kg/m^3 [a] (600 lbs/yd^3)	Above grade landfill refuse cells. 1:1
Balefill	5 (operated from 1971-74)	4 ha (9 ac) & 12 ha (30 A)	337,800 tonnes (372,155 tons)	250,000 m^3/ha (130,000 yd^3/ac)	800 kg/m^3 (1,350 lbs/yd^3)	Baled refuse, stacked. 1:9
Millfill	Active (since Dec. 1973)	7 ha (18 ac)	317,700 tonnes (350,000 tons)	127,840 m^3/ha (64,800 yd^3/ac)	653 kg/m^3 (1,100 lbs/yd^3)	Covered, milled; area filled. 1:7
Strip mine landfill	Active (since June 1971)	5.7 ha (14 ac)	105,000 tonnes (116,000 tons)	69,957 m^3/ha (37,027 yd^3/ac)	263 kg/m^3 (450 lbs/yd^3)	Refuse filled in strip mine excavation. 1:4
Permitted sanitary landfill	4 (operated from 1971-75)	4 ha (10 ac)	38,800 tonnes (42,750 tons)	25,155 m^3/ha (13,104 yd^3/ac)	386 kg/m^3 (652 lbs/yd^3)	Trench method. 1:1

(Continued)

TABLE 16 B. CHARACTERISTICS CONTRIBUTING TO THE IMPACT OF EACH LANDFILL ON GROUND AND SURFACE WATER

Landfill	Sediment type underlying landfill (from surface to bedrock) and average % clay	Depth to water from base of landfill	Average annual precipitation + deviation during study period	Potential volume of leachate	Strength of 1978-79 study in mg/l	Leachate[d] historical data in mg/l
Hillfill	Well sorted sands & gravels, 12 m (40 ft). Poorly sorted till, 12 m (40 ft). 4%	Mounded in hillfill.	86.49 cm (34.05 in) +27.23 cm (10.72 in)	27,057 m^3 (21.93 ac-ft)	COD 2,992 TDS 3,084 Na 380 SO_4 12,000	(39,680) (19,144) (900) (680)
Balefill	Sandy till, 15 m (50 ft). Glacial drift (clay, sand, gravel), 9-37 m (30-120 ft). Alluvial sands & gravels, 100 m (328 ft). 3%	35.1 m (115 ft)	65.88 cm (25.94 in) + 9.74 cm (3.84 in)	20,032 m^3 (16.02 ac-ft)	COD 967 TDS 3,801 Na 572 SO_4 2,040	(718) (2,241) (1,079) (---^{a})
Millfill	Glacial outwash (sands & gravels), 15 m (50 ft). 4%	6.1 m (20 ft)	83.69 cm (32.95 in) + 0.06 cm (0.02 in)	15,232 m^3 (12.86 ac-ft)	COD 23,690 TDS 19,500 Na 828 SO_4 519	
Strip mine landfill	Clayey decomposed spoil, 1.5-5 m (5-16 ft).	24.4 m (80 ft)	104.10 cm (40.98 in) + 6.92 cm (2.71 in)	13,059 m^3 (10.52 ac-ft)	COD 9,580 TDS 11,145 Na 1,500 SO_4 ---^{b}	
Permitted sanitary landfill	Till, 5 m (16 ft). 9%	15.2 m (50 ft)	78.60 cm (30.94 in) + 4.94 cm (1.94 in)	7,072 m^3 (5.80 ac-ft)	COD $17,799^c$ SC $8,320^c$ Na 281^c SO_4 171^c	

---

[a] Estimated value.
[b] Chemical interference suspected.
[c] Chemical interference.
[d] Boone County test cell 2D - mean value of analyses from four years following completion of cell.
[e] No historical data is available for the Millfill, the Strip Mine Landfill or the Permitted Sanitary Landfill.

tion during the study period, the potential volume of leachate and the strength of the leachate. Table 17 is a summary of the impact of each site on ground water as shown by representative downgradient wells.

So that comparisons easily can be made of the leachate produced by each landfill examined and that produced by other sites, where appropriate, several Figures are presented. Figure 61 shows Stiff diagrams constructed from both historical data and data collected during the four sampling rounds of the present study. The purpose of the diagrams is to illustrate both the relative strength of leachate for each type of landfill and the changes that occurred with time for each leachate. This information is presented using milliequivalents of sodium, iron, manganese, zinc, chloride, and sulfate. The historical data for the hillfill is from 1969 (see Appendix D) and that for the balefill is from 1974 to that part of 1978 prior to the present study period. Historical data for millfill leachate is represented by samples from Lysimeter #4, an 8-month old lysimeter of milled uncovered refuse at the milling project in Madison, WI.[2] The historical data for a permitted sanitary landfill is taken from leachate produced at Boone County test cell 2D for the year 1976; the test cell contained covered unprocessed waste.[3]

Several observations are apparent from the Stiff diagrams. The hillfill and the millfill produced the strongest leachates in terms of cations and anions. The hillfill, however, has considerably decreased in strength since 1969 except for concentrations of sulfate. Both diagrams for millfills demonstrate similar concentrations; this data, in both cases, was from relatively young milled refuse, but the concentrations of cations (except iron) and anions of leachate from the uncovered milled refuse were slightly higher than those from the milled covered refuse. The balefill has a leachate of low strength and, progressing from the historical data to the present data, a decrease in sodium concentration, but an increase in sulfate and chloride concentrations may be observed. The strip mine landfill has a leachate of moderate strength with a concentration between that of the millfill and that of the permitted sanitary landfill. Historical data was not available for a strip mine landfill. The diagrams for permitted sanitary landfill leachates present three to four-year-old leachate from Boone County test cell 2D and leachate approximately six years old from Facility III; these diagrams are very similar to each other and concentrations of cations and anions indicate leachates of moderate strength.[4,5]

TDS and COD concentrations with time are illustrated on Figures 62, 63, and 64; these parameters give a general indication of both the inorganic and organic strength of the

TABLE 17. IMPACT OF FIVE SITES SHOWN BY REPRESENTATIVE DOWNGRADIENT WELLS

Parameter[a]	Hillfill[b]		Balefill[c]	Millfill[c]	Strip mine landfill[d]		Permitted sanitary landfill[e]	
alkalinity	589	899	370	394	243	318	279	581
TOC	22.4	52.0	33.6	9.4	6.8	8.8	5.9	10.1
COD	52.0	131.8	71.5	8.7	11.7	17.3	0.55	14.3
TDS	922	1360	424	396	623	817	455	607
TKN	2.04	5.14	0.25	0.14	0.28	1.60	0.14	0.37
Na	12.1	115.1	24.3	7.78	6.5	50.0	5.9	66.7
DTW[f]	0		35 (115)	6.1 (20)	24.4 (80)		15.2 (50)	
distance[g]	42.7 (140)		0	133.2 (437)	42.1 (138)		0	
Avg. % clay	4%		3%	4%	---		9%	
PVL[h]	27,057 (21.93)		20,032 (16.02)	15,232 (12.86)	13,059 (10.52)		7,072 (5.80)	

a Chemical analyses expressed in mg/1.

b Downgradient wells, MP #4, #5, #9, and #10 showing minimum and maximum values.

c Downgradient well, MP #2.

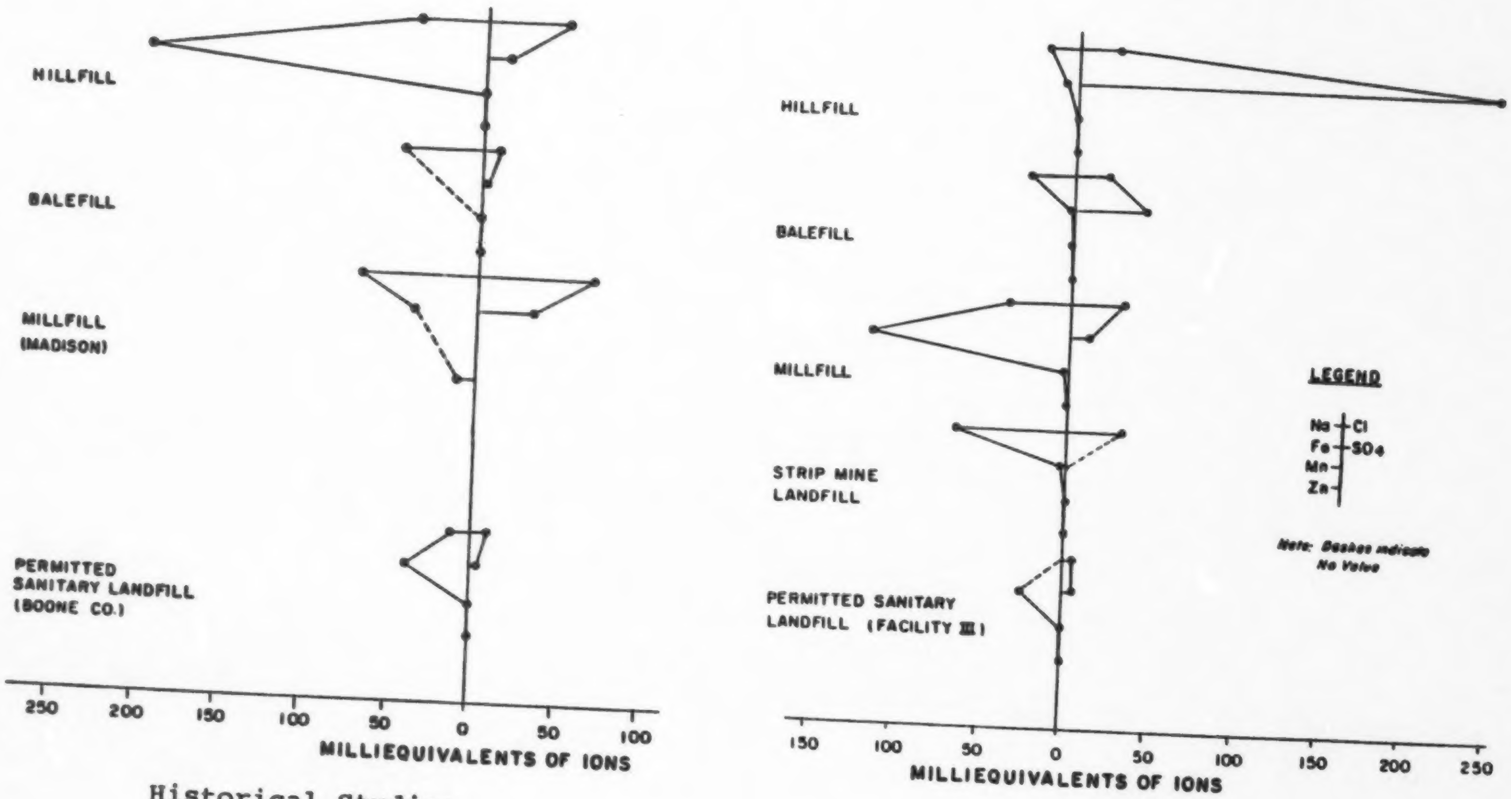
d Downgradient wells, MP #5 and #7 showing minimum and maximum values.

e Downgradient wells, MP #2 and #5 showing minimum and maximum values.

f Depth to water below landfill base in m (ft).

g Approximate distance between landfill and well(s) in m (ft).

h Potential volume of leachate in m^3 (ac-ft).



Historical Studies

1978-79 Study

Figure 61. Modified Stiff diagrams showing leachates from historical studies and the 1978-79 study.

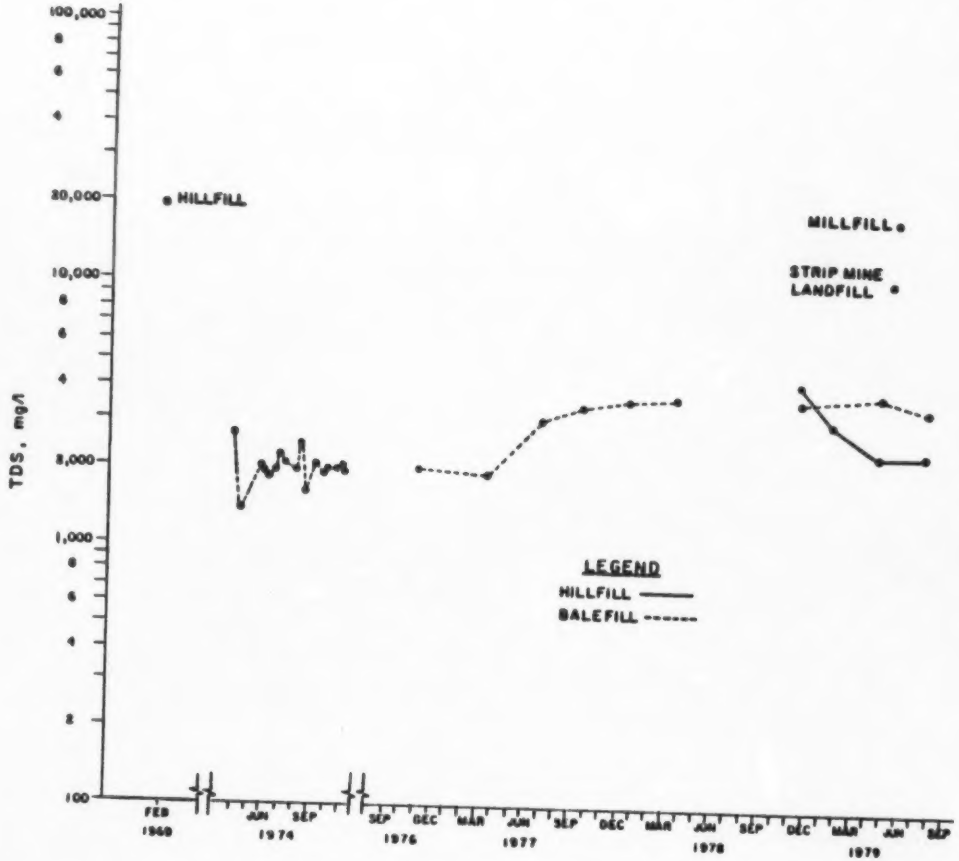


Figure 62. Graph of TDS concentrations with time of leachates from the hillfill, balefill, millfill, and strip mine landfill.

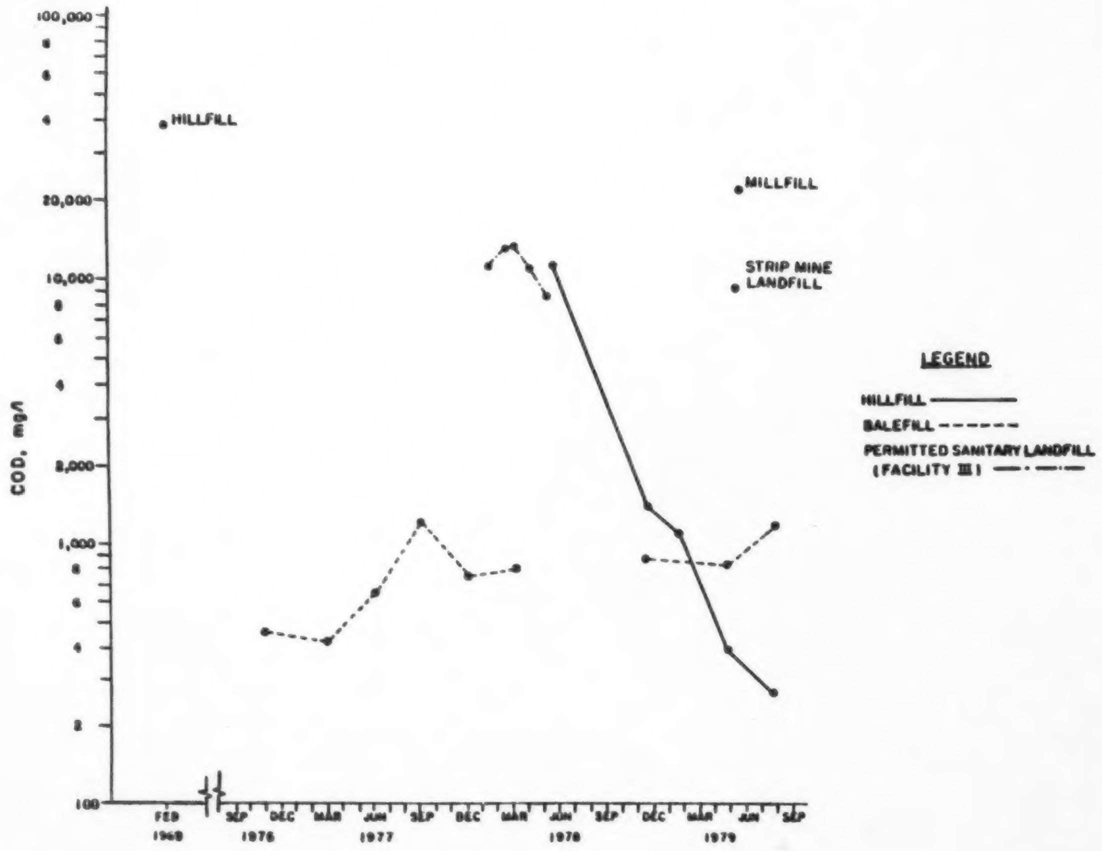


Figure 63. Graph of COD concentrations with time of leachates from the hillfill, balefill, millfill, strip mine landfill, and permitted sanitary landfill.

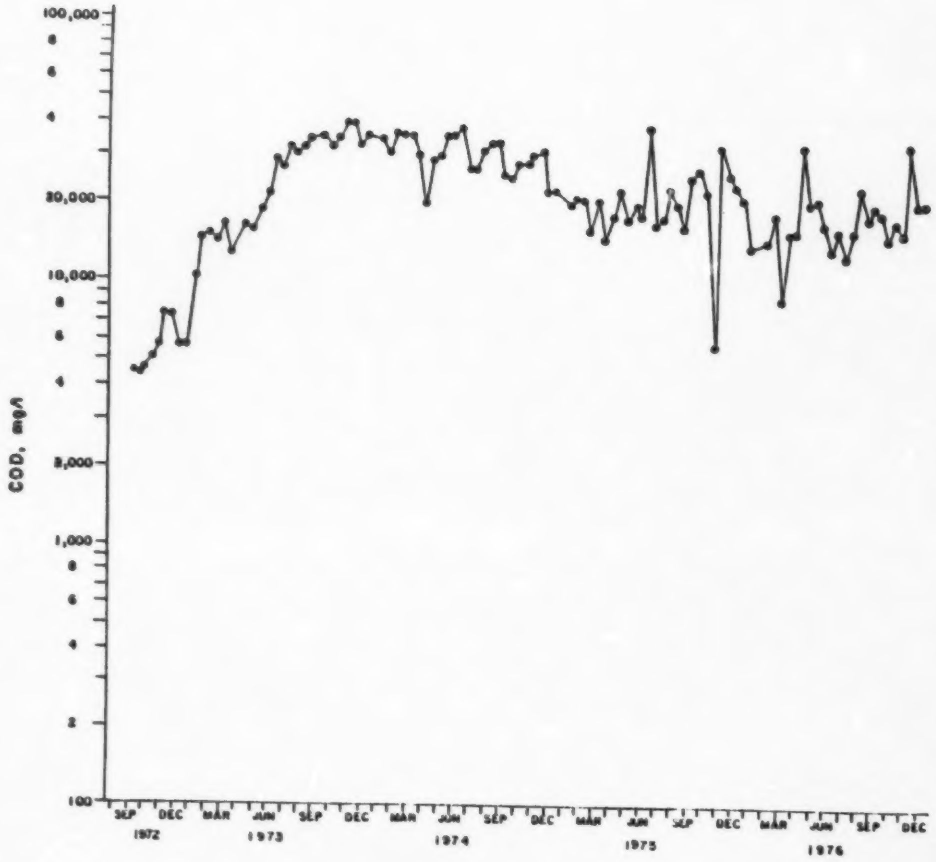


Figure 64. Graph of COD concentrations with time of leachate from the Boone County test cell 2D.

five leachates. These graphs illustrate the relative strength of the leachates produced by the five types of landfills and the trends of leachate with time; they also demonstrate different trends for the different types of landfills.

Figure 62 shows TDS concentrations with time for the hillfill, balefill, millfill, and strip mine landfill. The millfill, during 1979, had the highest TDS concentrations (19,500 mg/l); the hillfill leachate also showed considerable concentrations during 1969 (19,144 mg/l). The hillfill leachate has steadily decreased to a low concentration by July 1979; this concentration is even lower than those of the balefill leachate. The consistently low concentrations of TDS in the balefill leachate should be noted as well as the apparent plateau of concentrations between June 1977 and July 1979. Leachate from the strip mine landfill has a moderate concentration of TDS (11,145 mg/l).

Figure 63, showing COD levels over time for the hillfill, balefill, millfill, strip mine landfill and Facility III, exhibits trends and relative strengths of leachates very similar to those shown on Figure 62. The COD of the hillfill leachate in 1969 (39,680 mg/l) was the highest among all the leachates in the study, but it decreased with time to low levels by the end of 1979. The leachate from the permitted sanitary landfill (Facility III) was of moderate strength and is most similar to that from the strip mine landfill and that from the hillfill after 13 years of activity (May 1978). COD of the balefill leachate is the lowest and shows the same relationships as those of TDS, but seasonal variations are more apparent with COD; peaks are seen consistently in the late summer and early fall months.

Figure 64 shows COD concentrations for the leachate from Boone County test cell 2D. These levels of COD are relatively elevated indicating a strong leachate similar to that produced by the millfill and early in the history of the hillfill; it is stronger than that from the strip mine landfill, the balefill, and Facility III. Trends in the COD concentrations of this leachate are discussed in depth in Section 6, Permitted Sanitary Landfill.

These Tables and Figures are presented so that the reader may make comparisons concisely and rapidly among the landfills examined in this study; they should be referred to frequently during the study of this Section.

Hillfill

There are several problems inherent in hillfilling solid waste. Because of their height and shape, hillfills may not have the structural stability and lateral support that is found in the conventional method of landfilling. The steep slopes of a hillfill promote surface water runoff and, therefore, there is less infiltration of water than is found at the conventional type of landfill. In addition, because of the height of the refuse emplaced above the ground, a greater potential exists for ground-water mounding beneath such sites, particularly where the depth to the water table is relatively shallow. Gas production is also a common problem in hillfilling.

At the hillfill site investigated in the present study, these problems were observed. Leachate seeps between lifts and cells and the presence of leachate in the ground water indicate that there has been some rupturing of the clay cells within the hillfill. Ground water is apparently mounded within the hillfill itself (see Section 5, Hydrogeology of the Hillfill Site) and methane gas is present in and around the hillfill.

The leachate produced by the hillfill was of considerable strength (1969) but has decreased with time and, during the present study period, the hillfill produced a leachate of low to moderate strength (see Table 16B and Figures 61, 62, and 63). The potential volume of leachate at the hillfill is the highest among the five investigated landfills, 27,057 m3 (21.93 ac-ft).

In addition to these factors, there are characteristics of the hillfill site which either permit or limit pollution. The hillfill has had the greatest impact on ground water among all of the five sites studied based on the evaluation of downgradient water quality (see Table 17). However, certain site specific factors should be considered before comparing the hillfill with the other sites. The hillfill is the oldest of the landfills under consideration and was begun 13 years before the study period. The leachate produced by the hillfill during the 1978-79 study was of low to moderate strength; peak concentrations are long past and the hillfill is in its final stage of degradation (see Figures 61, 62, and 63). The hillfill contains approximately 272,340 tonnes (300,000 tons) of refuse with an average volume per area of 47,500 m^3/ha (25,000 yd^3/ac) which is considerably more than the quantity within the permitted sanitary landfill (see Table 16A). Furthermore, the monitoring wells surrounding the hillfill are close to it; those at the millfill and the strip mine landfill are located at greater distance (see Table 17).

A shallow depth to ground water is the characteristic of the hillfill site that has the greatest effect on its environmental impact (see Table 16B). When the hillfill was constructed, the base cells were emplaced in an excavation;

this further decreased the distance between the water table and the refuse. Depth to water in the wells surrounding the hillfill is shallow and there is considerable evidence that the ground water is mounded within the hillfill. This certainly increases the rate of decomposition and the movement of contaminants into the shallow ground water.

The hillfill is situated on glacial outwash which is quite permeable; the amount of clay averages four percent (see Table 16B). On the basis of borings completed around the hillfill in 1980, it appears that leachate and methane gas are present in the top of the saturated zone and often flow with ground water above clay layers within the outwash and till. The gradient of the ground-water mound within the hillfill is very steep; thus, ground water and leachate radiate outward from the hillfill in all directions. However, the gradient of the ground water surrounding the hillfill is low and so leachate is not rapidly dispersed after leaving the hillfill.

Several characteristics at the hillfill site retard the spread of pollution. These include the clay cells, the presence of clay layers within outwash, and the presence of the clayey till which underlies the outwash; these all attenuate contaminants. In addition, because of the permeability of the outwash, contaminants can be diluted.

Balefill

The method of landfilling baled solid waste has several characteristics which reduce the potential for pollution. Baling decreases the volume of refuse (see Table 16A) and thereby reduces the surface area exposed to infiltrating water. Because of the reduced surface area, the low permeability of the bales, the resulting pattern of water channeling between bales, the relatively short retention time for water within a balefill and the small amount of void space, a balefill rapidly reaches field capacity and therefore produces leachate in a shorter period of time than do other types of landfills. The leachate produced, however, is less concentrated than that produced by other types of landfills (see Figures 61, 62, and 63). A balefill will generate leachate for a longer period of time than will other types of landfills and the final stages of decomposition will be substantially delayed. Methane gas is produced by balefills but may be produced at a slower rate than is the case at other types of landfills.

Among the landfills studied, the balefill had the second highest potential volume of leachate at 20,032 m^3 (16.02 ac-ft); however the leachate was of the lowest strength (see Table 16B and Figures 62 and 63). It might be expected that the concentration of leachate would decrease slightly after the exterior of the bales had decomposed.[6] The historical data and the 1978-79 study, however, found that concentrations initially rose and then stabilized or continued to increase at a slow rate, in spite of the fact that the balefill was completed five years before the present study period (see Figures 62 and 63).

The balefill was well sited. It has the greatest depth to water and the largest amount of sediment above bedrock among the five sites studied (see Table 16B). Unfortunately, there is a relatively low average percentage of clay in the sediment; the till immediately underlying the balefill contains seven percent clay and the sands and gravels beneath that contain even less, only one to four percent clay. This amount of clay does not allow for significant attenuation by ion exchange. However, due to the great thickness of this unconsolidated material, there is enough clay present to provide attenuation. Furthermore, the large grain size and high permeability of the sediments beneath the till and a relatively steep ground-water gradient allow for rapid dilution and dispersion of contaminants.

The balefill is the second oldest of the five sites studied and contains approximately 337,800 tonnes (372,155 tons) of refuse. It has had a slight to moderate effect on the ground water adjacent to it (see Table 17). In general, the ground water at MP #2 shows comparatively low concentrations of inorganic material (TDS) but somewhat elevated levels of COD and TOC. This suggests that the clays in the till have become saturated with organic compounds and essentially have ceased to attenuate such material.

Millfill

The primary contamination problem inherent in the landfilling of milled refuse is the rapid decomposition of the refuse. Milling increases the surface area of refuse; the rate of physical-chemical leaching and biological decomposition is enhanced by increased surface area and by the more even flow of water through milled refuse than through unprocessed waste. The rapid rate of decomposition accelerates the rate at which gas is produced and at which organics are degraded.

The test cells at Madison, WI show that milled uncovered refuse produces a very strong leachate in a short time which stabilizes rapidly at relatively low concentrations.[7] It produces a larger volume of leachate more rapidly than does covered refuse, milled or unprocessed. The milled covered refuse exhibited peak concentrations that were lower than those for milled uncovered refuse. It reached these concentrations in a relatively longer period of time; milled covered refuse behaved more similarly to unprocessed covered refuse than to milled uncovered refuse. Milled uncovered refuse stabilized after 1 to 1-1/2 years; however, milled covered refuse was still not stable after three years.

The millfill had a potential volume of leachate of 15,232 m^3 (12.86 ac-ft) and contained a large amount of refuse, 317,700 tonnes (350,000 tons). The average volume per unit area was high, 127,840 m^3/ha (64,800 yd^3/ac) second only to that for the balefill (see Table 16A). The leachate was of considerable strength (see Table 16B and Figures 61, 62, and 63).

Several factors at the millfill site permitted it to pollute. The depth to water was approximately 6 m (20 ft) or less and the millfill was underlain by a permeable outwash. The outwash had a low percentage of clay (four percent) which provided little potential for the attenuation of contaminants by ion exchange. The steep gradient of the ground water, however, and the permeability of the outwash allowed dilution and dispersion of contaminants.

The impact of the millfill on ground water was slight to moderate (see Table 17) and localized as may be seen by the presence of potable water at MP #1 (see Section 5. Water Chemistry at the Millfill Site). The downgradient wells are generally farther from the millfill than are such wells at the other sites in the present study. The refuse in the southwest corner of the millfill was emplaced during 1974, 1975, and 1976; thus, there were from two to three years between the completion of filling in that area and the present study period and ground water at MP #2, downgradient from the southwest corner, contained low concentrations of organics (see Table 17). MP #6 and #7, receiving newer leachate, showed slightly higher organic concentrations (see Section 5, Water Chemistry at the Millfill Site). These observations are consistent with the trends that may be expected from milled refuse and the effect of leachate generated by it.

Strip Mine Landfill

A strip mine landfill has certain pollution potentials that are inherent only to this method of landfilling. The primary condition for the probability of contamination at a strip mine landfill is the lack of soil or unconsolidated sediment between the base of the landfill and the ground water. The low permeability of underlying shale bedrock causes contaminated water to move along bedding planes, joints and fractures directly and often rapidly to the ground and surface water.[8] The steep slopes characteristic of many coal regions contribute to increased surface runoff which may carry leachate from breakouts directly to nearby surface water. Furthermore, steep slopes encourage erosion and maintenance problems which also increase the potential for leachate breakouts. Ground water in strip mined areas has commonly been affected by acid mine drainage prior to landfilling. This is demonstrated by elevated iron, sulfate, total dissolved solids, and manganese concentrations and lower pH in such waters.

Conditions at a strip mine landfill may vary considerably from region to region. A study of the Frostburg and Westernport sites indicates that some problems can be ameliorated by lower slopes, diverted surface runoff, and varying amounts of soil placed beneath the refuse.[9] It also indicates, as does the present study, that leachate neutralizes the low pH caused by acid mine drainage.[10] Another study indicates that strip mine landfills have a minor impact on the environment except when placed near ground or surface water; strip mine landfills commonly contaminate local streams because of proximity.[11]

The strip mine landfill investigated in the present study produced a leachate of moderate strength (see Table 16B) comparable to other leachates generated by unprocessed waste (see Figures 61 and 63). The landfill had a low to moderate potential volume of leachate, 13,059 m^3 (10.52 ac-ft) and an average volume of refuse per area, 69,957 m^3/ha (37,027 yd^3/ac), nearly three times that at the permitted sanitary landfill (see Table 16A).

In addition to pollution factors inherent to strip mine landfilling, there are several characteristics of the specific site which allow the landfill to pollute. Ground water in the vicinity flows to the southeast; however, the shale bedrock dips in the opposite direction (northwest). This dip of the beds is responsible for contamination reaching ground water upgradient of the landfill (seen at MP #5). The steep slope at the strip mine landfill promotes considerable quantities of surface runoff; the runoff carries leachate from surface seeps downslope to surface water (MP #9) and the stream (MP #2). Fractures that underlie the stream and fractures that intersect it and then continue beneath portions of the landfill may carry leachate to the stream. Although the strip mine landfill is approximately 106 m (350 ft) from the stream at its closest point, decreasing concentrations of tested parameters between MP #2 and MP #1 show that the stream has been affected by leachate (see Section 5, Water Chemistry at the Strip Mine Landfill Site).

Because of the complex nature of ground-water movement in the shale bedrock (having low permeability), there is a comparatively small potential for the dilution and dispersion of contaminants. Furthermore, the gradient of ground water in the vicinity of the strip mine landfill is not very steep.

In spite of the relatively high pollution potential of a strip mine landfill, the impact on ground and surface water at the strip mine landfill investigated during the present study has been moderate. This finding may be attributable, in part, to the distance between the landfill and the monitoring wells (see Table 17). In addition, the landfill is relatively young and most of the refuse has been emplaced during the past four years; a relatively small amount of refuse had been emplaced by the end of the study period, 105,000 tonnes (116,000 tons), see Table 16A. Before landfilling commenced, clayey spoil material had been placed in the base of the strip cut which may provide minimal attenuation of leachate. In addition, because there are approximately 24.4 m (80 ft) between the base of the landfill and the top of the water table, the leachate moves under conditions which allow degradation to occur.

Permitted Sanitary Landfill

The conventional method of sanitary landfilling has several pollution problems associated with it. Generally, two methods of filling are employed: the area lift and the trench methods. The permitted sanitary landfill examined in the 1978-79 study was constructed using the trench method and a refuse density of approximately 386 kg/m^3 (652 lb/yd^3) was achieved which is average for unprocessed solid waste. Because of the relatively low degree of refuse compaction and the varied size and random distribution of the materials landfilled, the flow of water through a conventional landfill is frequently channeled and rather uneven. This promotes irregular decomposition of refuse and creates areas of more rapid decomposition as well as areas of relative inactivity. However, because of the relatively low degree of compaction and the greater amount of cover material used compared to processed waste disposal sites (cover to refuse ratio 1:1 at the permitted sanitary landfill, see Table 16A), there is a greater potential for the attenuation of contaminants by ion exchange with clays if the cover material has a sufficient percentage of fines.

The permitted sanitary landfill examined during the 1978-79 study had a comparatively small potential volume of leachate, 7,072 m^3 (5.80 ac-ft). Unfortunately, leachate could not be collected from this landfill. Therefore, leachate from two other sources, Facility III and Boone County, Kentucky, test cell 2D are used in this study as a basis for the comparison of chemical data concerning leachate production and composition.[12,13] Data was collected at

Facility III, a permitted sanitary landfill very similar to the one studied in 1978-79, from a leachate seep present during five months of a twelve-month study (1978). The Boone County field-scale test cell 2D was constructed in August 1972 in an excavation 8.53 m (28.0 ft) square and 3.20 m (10.5 ft) deep. It was lined with polyethylene, filled with refuse compacted by bulldozer to a density of 598 kg/m^3 (1,008 lb/yd^3), and covered with 0.30 m (1.0 ft) of compacted soil. A berm grid was placed above the cover material using 0.15 m (0.5 ft) berms in order to promote uniform percolation (and eliminate runoff) into the cell. Leachate from the collection system beneath the refuse was sampled and analyzed from September 1972 through December 1976.

Typically, a permitted sanitary landfill produces a strong to moderate leachate for a long period of time. The final stage of anaerobic degradation within a landfill including organic decomposition, methane production, and pH neutralization, occurs after a comparatively long period and leachate concentrations do not stabilize at lower levels rapidly.

Leachate produced by permitted sanitary landfills varies considerably from one to another depending on specific operational differences, hydrologic differences and age, but commonly ranges from moderate to considerable strength. The leachate from Facility III (operated from July 1971 to July 1973) was of moderate strength even five years after completion (see Figures 61 and 63); that from the Boone County test cell was strong (see Table 16B and Figures 63 and 64) because of the higher density of the refuse, the uniform infiltration of water and the absence of runoff.

The trend of the leachate from the Boone County test cell, see Figure 64, indicates that the leachate reached peak concentrations between 1-1/4 and 1-7/8 years after completion of the cell; this trend is confirmed by declines in specific conductance and pH.[14] COD concentrations, approximately 2-1/2 years following completion, dropped to one-half of their peak levels but were still significantly elevated. After 4-1/4 years, there were no signs of further decreasing concentrations. Seasonal variations increased during this period. The graph demonstrates that a strong leachate has been produced for a long period of time.

The permitted sanitary landfill investigated during the 1978-79 study has certain site characteristics which affected the impact that this landfill has had on ground and surface waters. This is the third oldest among the five landfills studied (see Table 16A) and contains the smallest amount of refuse, 38,800 tonnes (42,750 tons). As might be expected, it has the lowest volume of refuse per area among the five landfills, see Table 16A.

The permitted sanitary landfill investigated in the present study is underlain by at least 5 m (16 ft) of glacial till which contains approximately nine percent clay, the highest percentage of clay found among the five sites, see Table 16B. In addition, the amount of cover material (glacial till) used during landfilling (cover to refuse, 1:1, see Table 16A) provided significant attenuation of pollutants. Furthermore, there is a substantial depth to ground water beneath the landfill (see Table 16B) and because of its location on a ground-water divide and the resulting steep ground-water gradient, there has been relatively rapid dispersion of contaminants.

Because of the combination of methodological and site specific factors, the permitted sanitary landfill has had only a slight to moderate impact on ground water (see Table 17) and essentially no impact on surface water (see Section 5, Water Chemistry at the Permitted Sanitary Landfill Site). On the basis of historical data and that from the 1978-79 study, the impact on the ground water surrounding the landfill has apparently begun to diminish. However, the quality of the ground water beneath the landfill (shown by MP #3, see Section 5, Water Chemistry at the Permitted Sanitary Landfill Site) has remained consistent throughout the period of data collection.

ADVANTAGES AND DISADVANTAGES OF THE SPECIAL TYPES OF LANDFILLS COMPARED TO A CONVENTIONAL PERMITTED SANITARY LANDFILL

It is useful to take the permitted sanitary landfill as a base line or standard and to compare the special types of landfilling to it (and to each other) in order to determine the relative advantages and disadvantages that each may offer.

If a permitted sanitary landfill is properly sited, it will have only a minor impact on ground and surface water as is evidenced by the permitted sanitary landfill examined in the present study, see Section 5, Water Chemistry at the Permitted Sanitary Landfill Site. The primary advantage of a permitted sanitary landfill is the relatively low cost of operation compared to that for processed waste. Disadvantages include the large area required for landfilling and the cost of suitable land. Settlement and the long duration of the processes of degradation limit the possible subsequent uses of the land. In addition, vectors, blowing paper, and odors are problems common to this method of landfilling and often incur negative public reactions.

Hillfilling

The major advantage of the method of hillfilling refuse is that it reduces the amount of land required. It increases the volume per area by stacking refuse to a considerable height. In addition, because of the steep slopes of a hillfill, infiltration is minimized; this reduces the potential volume of leachate. Furthermore, because of its relatively small base, this type of landfill lends itself well to a leachate collection system.

The disadvantages of hillfilling include the fact that a hillfill may be less structurally stable than a permitted sanitary landfill and that leachate breakouts between lifts and cells may occur. Gas production also may be a problem. In addition, the steep slopes of a hillfill increase runoff which contributes to erosion and causes maintenance problems.

Completed hillfills are commonly used as recreational areas such as parks, ski slopes and sledding hills.

Balefilling

The primary advantage in balefilling refuse is volume reduction. Effective landfill density can be increased approximately 50 percent compared with a permitted sanitary landfill.[15] Void space within the landfill is reduced and structural stability is increased. Blowing paper, fires, odors, and vectors are minimized; public reaction to a balefill is generally good. A balefill produces a lower strength leachate for a longer period of time in comparison with a permitted sanitary landfill or, indeed, any other type of landfill considered in this study; therefore, there may be less potential for the severe contamination of ground and surface waters and fewer problems with gas.

Less cover material is needed at a balefill than at a permitted sanitary landfill, hillfill, or strip mine landfill. Less equipment is needed at the site and it is more easily maintained; only a forklift and small front-end loader are necessary. Trucks suffer less wear traversing a balefill than a conventional landfill site. In addition, if the baling facility is centrally located for collection trucks, there will be less driving time and fuel consumption. The dense regularly-shaped bales are an optimum form for efficient transportation. Resource recovery is facilitated at the baling plant; as refuse travels along conveyor belts, metals and corrugated cardboard are easily removed for recycling.

The disadvantages of baling refuse include the costs for the equipment at the baling facility; these may be partially offset by the economic advantages previously discussed. Careless operation and stacking at the balefill site may forfeit much of the benefit of volume reduction. Finally, if refuse bales are placed proximal to water or in an area where ground water may reach them during wet periods, there will be considerable pollution potential.

The possible uses of a balefill site after completion are greater than those at a permitted sanitary landfill because of the stability of the balefill. Completed balefills may be used for recreational areas, parking lots, and even light building structures.

Millfilling

Landfilling milled refuse has some advantages similar to those of landfilling baled refuse. The primary advantage is that of volume reduction. Shredded refuse, when compacted by a bulldozer at the site, obtains high density. A millfill is structurally more stable and has less settlement than a permitted sanitary landfill because of its relative density. The increased volume of refuse within a smaller area and the fact that the decomposition of refuse at a millfill is comparatively rapid and produces higher concentrations of leachate are factors that facilitate leachate collection and treatment. If a millfill is properly sited and there is a substantial separation between the millfill and the ground water, the rapid decomposition and shorter time period needed for stabilization within the landfill become advantageous.

The public is generally more receptive to a millfill site than to a conventional sanitary landfill because blowing papers, vectors, and odors are reduced. Resource recovery is facilitated at the millfill plant, a further advantage of millfilling compared to conventional landfilling. As with a balefill, less cover material is needed and there are more efficient transport and landfilling procedures, including the diminished use of trucks and less damage to the vehicles at the millfill site. However, after milled refuse is received at the landfill site, it must be spread and compacted by bulldozers. At a balefill, bales need only be forklifted into place from the transfer trucks and so less time and equipment are required.

The cost of running a milling facility is a major disadvantage of this method. In addition, if a millfill is not properly separated from ground and/or surface water, the strong leachate produced by a millfill could have a severe effect on the environment.

A completed millfill, like a balefill, has a greater range of potential uses compared to a permitted sanitary landfill. This is a result of increased structural stability.

Uses include development as parks and recreational areas and parking lots.

Strip Mine Landfilling

Because of the existing strip pits, previously excavated cover material (spoil), and existing access roads, a strip mine landfill can be operated at a relatively lower cost than a permitted sanitary landfill or either method of volume reduction landfilling. This method of landfilling has the additional benefit of land reclamation being simultaneously accomplished. Another possible advantage to this method of landfilling might be the presence of railroads leading to major cities which would facilitate the long-range transport of wastes from metropolitan areas.

Because of excavation which creates substantial highwalls in many strip mines, the volume of refuse per area may be increased in comparison with a permitted sanitary landfill. Steep slopes may minimize infiltration and therefore decrease the potential volume of leachate generated. The leachate produced by a strip mine landfill should be similar to that produced by a permitted sanitary landfill. It tends to neutralize acidity from acid mine drainage. Underclays that often are present beneath coal control leachate migration.

Disadvantages of strip mine landfilling include the absence of significant thicknesses of soil for the attenuation of leachate which increases the pollution potential of the landfill. The complex hydrogeologic conditions that are associated with coal measures frequently increase the potential for contamination; examples are the presence of perched water tables, underclays, and impermeable shales as well as a potential for the channeling of contamination through fractures and bedding planes. The steep slopes that are often found at strip mine landfills may promote erosion and maintenance problems that are not found at permitted sanitary landfills, balefills, or millfills.

A strip mine landfill would be subject to blowing paper, vectors, and odor problems similar to those of the conventional type of landfill. However, because of the remoteness of most strip mining areas, less public reaction to this type of landfill may be anticipated. Because of their relative remoteness, the transportation of refuse from the place where it is generated to the landfill site may involve greater distances at strip mine landfills than at other types of landfills. In addition, in the event that mining were to be resumed at a completed strip mine landfill, environmental hazards and danger to miners could result from efforts to remove refuse emplaced near the highwall. These include the necessity of finding an alternative location for the partially-decomposed refuse and the need to protect people handling such materials from the effects of methane gas.

The uses of completed strip mine landfills are limited because they generally lack proximity to populous areas. If such a landfill is near an urban area, it could be used as a recreational site. Otherwise, such sites are primarily reclaimed for aesthetic reasons.

PROJECTION OF THE OPTIMUM APPLICABILITY OF THE FIVE TYPES OF LANDFILLS TO VARIOUS GEOGRAPHIC AREAS

When projecting the applicability of the methods of landfilling discussed in this report, a primary consideration is the potential contamination of ground and surface waters. Among the factors that must be considered when siting landfills, climate is perhaps the most important because the relationships between precipitation, temperature, and evapotranspiration determine the amount of recharge to an area. The amount of recharge is also affected by topography and vegetation. Recharge multiplied by the area of the base of a landfill yields the potential volume of leachate, the factor by which the effect of a landfill on the environment is measured.

The geology, soils, and topography of a region determine the capacity of the natural surroundings of a landfill site to accept and attenuate pollutants. The type of bedrock (and/or surficial geologic deposits) beneath a landfill are of basic importance because they determine the characteristic soils and topography of an area. Geology also influences ground-water movement. Depending on the type of bedrock and the climate, physical and chemical weathering processes produce varying conditions such as shallow depth to bedrock (shallow soils), thick saprolite, and even problems such as sinkholes in limestone terrain. The conditions that are most desirable for a landfill site because they promote attenuation include the presence of thick saprolite, thick deposits of glacial till, other glacial sediments containing clay and other unconsolidated sediments containing significant amounts of clay. The presence of sand or gravel is undesirable except in that they increase permeability and thereby increase the amount of dilution and dispersion of contaminants. The absence of soil and/or unconsolidated sediment is undesirable.

The characteristics of the ground water in an area is a primary concern. It is imperative that a substantial distance exist between the base of a landfill and the top of the water table; all types of landfills have a great potential for the severe contamination of ground-water resources if they are located within the ground water. Even if a landfill is located above the apparent level of the water table, seasonal variations and the tendency for mounding of ground water within landfills must be considered. The natural quality of the ground water should also be considered. If it has already been degraded by geologic conditions, for example, acid mine drainage, or if the ground water is saline as in coastal areas, a landfill will have a relatively diminished impact since such ground water cannot be considered for use without treatment.

Finally, the population of an area should be considered. The density of population determines the amount of refuse produced and the rate at which it is produced. It also affects the availability and cost of useful land. Considerations of population may affect the preference for employing volume reduction methods of landfilling compared to using conventional methods.

The combination of the factors presented above makes certain methods of landfilling more desirable in particular geographic areas of the country or where certain socioeconomic conditions prevail.

Hillfill

Because a hillfill increases the volume of refuse per area and thus reduces the amount of land required for landfilling, hillfills are particularly suitable for densely populated areas. In addition, because their steep slopes increase surface runoff and minimize infiltration, the potential volume of leachate is reduced. Therefore, a hillfill may be preferred over other methods of landfilling in humid regions. However, because of the greater potential for ground water mounding beneath a hillfill, care must be taken to avoid areas with a shallow depth to ground water.

Balefills

Since balefilling greatly reduces the volume of refuse and facilitates resource recovery, it is a preferred method for densely populated regions. Because a balefill produces a leachate of low strength and has a relatively low potential for contamination, balefilling might be the best method of landfilling for the humid south, especially in areas with a shallow depth to water, and in sandy coastal areas with relatively little potential for attenuation. The benefits of balefilling generally are not applicable to arid regions because such areas are usually less populated. The environmental advantage of having a lower pollution potential is diminished in arid regions because the potential volume of leachate in such regions would be small for any type of landfill.

Millfills

A millfill produces a strong leachate and so such a landfill would be best located in areas having thick deposits of unconsolidated sediments containing significant amounts of clays. The glaciated northeast, the Great Lakes region, and the Piedmont province in both the northeast and the humid south are examples of areas suitable for millfills. They characteristically have geologic materials that can attenuate the relatively strong and rapidly-produced leachate of a millfill, provided there is a substantial depth to water beneath the landfill. Millfilling reduces the volume of refuse and the size of the area needed for landfilling, considerations which are advantageous in the densely populated eastern portions of the country.

Strip Mine Landfills

Strip mine landfills are limited to areas of the country which have been strip mined. Those located in the arid west have the benefit of a climate that tends to limit the potential volume of leachate. Strip mine landfills are advantageous primarily because strip mining areas are sparsely populated and the previous development of the site for mining offers certain economic benefits.

Permitted Sanitary Landfills

The conventional method of landfilling solid waste is applicable throughout the country, but particularly in sparsely populated arid areas where landfilling by the trench method would offer the advantage of relatively low cost. The conventional method of landfilling is also desirable in glaciated regions and in older eroded mountainous regions where saprolite is found. Use of the permitted sanitary landfill (trench method) is not recommended for the humid south or coastal plain regions because of the shallow depth to water typical of such areas. Excavations for trenches decrease the distance to the water table and thus increase the pollution potential of the landfill.

REFERENCES

1. Donahue, Jack and Harold B. Rollins, ed. Geology of the Northern Appalachians Field Trip Guidebook. Department of Geology and Planetary Science, Pittsburgh, PA, 1979, p.7.

2. Ham, Anderson, Stegmann, Stanforth. Background study on the development of a standard leaching test. Environmental Protection Agency, Office of Research and Development, EPA-600/2-79-109, May 1979, p.50.

3. Wigh, R. Boone County field site interim report test cells 2A, 2B, 2C, and 2D. U.S. Environmental Protection Agency Report 600/2-79-058, 1979, pp.124-159.

4. Wigh. Boone County field site, pp.106-123.

5. A. W. Martin Associates. Evaluation of the effect of landfill Facility III on ground and surface water resources, U.S. Environmental Protection Agency, Office of Solid Waste Management, 1979 (Unpublished report, WH-564), Appendices D and E.

6. Bale out of solid waste problems. American City & Country, 95(6) :75-77, June 1980, p.75.

7. Reinhardt, J. J., and R. K. Ham. Final report on a milling project at Madison, Wisconsin to investigate milling of solid wastes, 1966-1972, v.1. U.S. Environmental Protection Agency, Office of Solid Waste Management. Milwaukee, The Heil Co., 1973, pp.48-63.

8. Emrich, G. H., and R. A. Landon. Investigation of the effects of sanitary landfills in coal strip mines on ground water quality. Pennsylvania Department of Environmental Resources. Bureau of Water Quality Management, Publication No. 30, 1971, pp.35-38.

9. Maryland Department of Health & Mental Hygiene. Use of abandoned strip mine for disposal of solid waste in Maryland, 1973, pp.18-47.

10. Maryland Department of Health & Mental Hygiene. Use of abandoned strip mine for disposal of solid waste, pp.47 and 57.

11. Emrich and Landon. Strip mine landfills' effects on ground-water quality, pp.37-38.

12. A. W. Martin Associates, pp.62-77.

13. Wigh. Boone County field site, pp.105-177.

14. Wigh. Boone County field site, pp.106-123.

15. Stone, R. Evaluation of solid waste baling and balefills, v.1 and 2. Environmental Protection Publication SW-iiic.1. Washington, U.S. Government Printing Office, 1975, p.102.

BIBLIOGRAPHY

Baedecker, M. J., and W. Back. Hydrogeological process and chemical reactions at a landfill. Ground Water, 17(5): 429-437, September-October 1979.

Bale out of solid waste problems. American City & Country, 95(6) :75-77, June 1980.

Beck, Jr., W. M. Building an amphitheater and coasting ramp of municipal solid waste. Environmental Protection Report SW-52d. Washington, U.S. Government Printing Office, 1973. 66p.

Chian, DeWalle. Evaluation of leachate treatment, v.1: Characterization of leachate. U.S. Environmental Protection Agency, Environmental Protection series, EPA-600/2-77-186a, September 1977. 210p.

Emrich, G. H., and R. A. Landon. Investigation of the effects of sanitary landfills in coal strip mines on ground water quality. Pennsylvania Department of Environmental Resources. Bureau of Water Quality Management, Publication No. 30, 1971. 39p.

Ham, Anderson, Stegmann, Stanforth. Background study on the development of a standard leaching test. Environmental Protection Agency, Office of Research and Development, EPA-600/2-79-109, May 1979. 248p.

A. W. Martin Associates. Evaluation of the effect of landfill Facility III on ground and surface water resources, U.S. Environmental Protection Agency, Office of Solid Waste Management, 1979 (Unpublished report, WH-564). 101p.

Maryland Department of Health & Mental Hygiene. Use of abandoned strip mine for disposal of solid waste in Maryland, 1973. 193p.

Reinhardt, J. J., and R. K. Ham. Final report on a milling project at Madison, Wisconsin to investigate milling of solid wastes, 1966-1972, v.1. U.S. Environmental Protection Agency, Office of Solid Waste Management. Milwaukee, The Heil Co., 1973. 127p.

Stone, R. Evaluation of solid waste baling and balefills, v.1 and 2. Environmental Protection Publication SW-iiic.1. Washington, U.S. Government Printing Office, 1975. 152p.

Wigh, R. Boone County field site interim report test cells 2A, 2B, 2C, and 2D. U.S. Environmental Protection Agency Report 600/2-79-058, 1979. 192p.

APPENDIX A

WELL LOGS

WELL LOGS - HILLFILL

MP #2
Date Drilled: December 1, 1972

Depth	Description
0 - 24.0 m (0 - 80.0 ft)	Drilled into Hillfill; alternating layers of refuse and cover.

MP #1, #3, #4
Date Drilled: December 7, 1972

Depth		Description
0 - 2.1 m	(0 - 7.0 ft)	Grey clay fill.
2.1 - 2.7	(7.0 - 9.0)	Brown sandy silt.
2.7 - 3.8	(9.0 - 12.5)	Sandy gravel.
3.8 - 4.1	(12.5 - 13.5)	Black organic silt; wood fragments at 4.1 m (13.5 ft).
4.1 - 5.2	(13.5 - 17.0)	Brown sandy clay.
5.2 - 7.2	(17.0 - 23.5)	Wet gravel.
7.2 - 7.3	(23.5 - 24.0)	Grey silty clay.
7.3 - 8.2	(24.0 - 27.0)	Sand and gravel; MP #4 completed at 7.9 m (25.9 ft).
8.2 - 8.7	(27.0 - 28.5)	Lense of sand and gravel.
8.7 - 9.4	(28.5 - 30.8)	Silt.
9.4 - 18.0	(30.8 - 59.0)	Gravel mixed with clay and silt; MP #3 completed at 11.9 m (39.0 ft).
18.0 - 19.2	(59.0 - 63.0)	Fine sand, silt and clay; MP #1 completed at 19.0 m (62.4 ft).

WELL LOGS - HILLFILL
(Continued)

MP #5, #6
Date Drilled: December 9, 1972

Depth	Description
0 - 1.5 m (0 - 5.0 ft)	Till cover.
1.5 - 6.9 (5.0 - 23.0)	Brown sandy gravel; MP #5 completed at 5.2 m (17.2 ft).
6.9 - 9.9 (23.0 - 32.5)	Wet grey silty sand.
9.9 - 12.0 (32.5 - 39.4)	Sand; MP #6 completed at 10.6 m (34.8 ft).
12.0 - 17.7 (39.4 - 58.0)	Sandy silty clay; caved at 12.2 m (40.0 ft).

MP #9
Date Drilled: October 24, 1973

Depth	Description
0 - 1.5 m (0 - 5.0 ft)	Brown sandy clay.
1.5 - 3.0 (5.0 - 10.0)	Brown sandy clay with gravel.
3.0 - 4.6 (10.0 - 15.0)	Gravely with sandy clay, some cobbles.
4.6 - 6.1 (15.0 - 20.0)	Grey clay, some gravel.

MP #10
Date Drilled: November 14, 1978

Depth	Description
0 - 2.6 m (0 - 8.4 ft)	Medium to coarse gravel, some silt and clay, light brown.
2.6 - 3.6 (8.4 - 11.8)	Medium to coarse sand and gravel, some clay. Moist.
3.6 - 4.4 (11.8 - 14.3)	Fine to medium sand, some silt and clay, brown.
4.4 - 5.0 (14.3 - 16.2)	Coarse to medium sand, some gravel and silt, grey. Wet at 4.7 m (15.5 ft).
5.0 - 7.6 (16.2 - 25.0)	Medium to coarse gravel and fine to coarse sand, trace of silt and clay, grey.

WELL LOGS - HILLFILL
(Continued)

MP #11
Date Drilled: October 14, 1974

Depth		Description
0 - 0.9 m	(0 - 3.0 ft)	Top soil.
0.9 - 3.0	(3.0 - 10.0)	Brown clay.
3.0 - 4.5	(10.0 - 15.0)	Grey clay.
4.5 - 10.5	(15.0 - 35.0)	Gravel.
10.5 - 13.7	(35.0 - 45.0)	Grey clay.
13.7 - 14.3	(45.0 - 47.0)	Gravel.
14.3 - 21.3	(47.0 - 70.0)	Grey clay.
21.3 - 25.0	(70.0 - 82.0)	Sand and gravel.
25.0 - 45.7	(82.0 - 150.0)	Dolomite.

MP #12
Date Drilled: November 14, 1978

Depth		Description
0 - 0.5 m	(0 - 1.5 ft)	Black organic silty clay.
0.5 - 0.8	(1.5 - 2.5)	Brown silty clay.
0.8 - 1.5	(2.5 - 5.0)	Loess, some gravel.
1.5 - 2.6	(5.0 - 8.5)	Grey silty clay. Damp.
2.6 - 3.4	(8.5 - 11.0)	Yellow brown medium to coarse sand, some silt and clay. Wet at 2.6 m (8.5 ft).
3.4 - 4.6	(11.0 - 15.0)	Gravel and medium to coarse sand, some silt, brown.

Well logs for MP #13 and #15 were incomplete or unavailable.

WELL LOGS - BALEFILL

MP #2
Date Drilled: August 15, 1978

Depth		Description[a]
0 - 3.0 m	(0 - 10.0 ft)	Brown silt and clay, some medium to coarse sand and fine gravel, fill.
3.0 - 12.2	(10.0 - 40.0)	Very fine to fine gravel, coarse to very coarse sand, brown silt.
12.2 - 21.3	(40.0 - 70.0)	Medium to very coarse sand, some very fine gravel and fragments, trace of fine sand and silt.
21.3 - 24.4	(70.0 - 80.0)	Very fine to fine gravel and medium to coarse sand, some small fragments and fine sand, trace silt.
24.4 - 30.5	(80.0 - 100.0)	Medium to coarse gravel, medium to coarse sand, some fragments and fine sand, trace silt.
30.5 - 33.5	(100.0 - 110.0)	Fine to medium sand, some coarse sand and fine to medium gravel, trace of fragments and silt.
33.5 - 39.6	(110.0 - 130.0)	Fine to coarse sand and medium to coarse gravel.
39.6 - 48.8	(130.0 - 160.0)	Brown silt, fine to coarse sand and very fine gravel, trace of fragments.
48.8 - 51.8	(160.0 - 170.0)	Light brown fine sand, trace of coarse sand.
51.8 - 60.4	(170.0 - 198.0)	Fine to medium gravel, some medium to coarse sand, trace of fine sand and silt.

[a] Colors where not indicated variegated grey to brown.

WELL LOGS - BALEFILL
(Continued)

MP #6

12.2 - 15.2	(40.0 - 50.0)	Fine to medium gravel, trace of coarse sand.
15.2 - 18.3	(50.0 - 60.0)	Very fine to medium gravel, some brown silt, clay and coarse sand.
18.3 - 21.3	(60.0 - 70.0)	Coarse to very coarse sand and very fine to fine gravel, trace of brown clay and silt.
21.3 - 24.4	(70.0 - 80.0)	Fine to medium gravel and medium to coarse sand, trace of brown clay and silt.
24.4 - 27.4	(80.0 - 90.0)	Fine to medium gravel and medium to coarse sand.
27.4 - 39.6	(90.0 - 130.0)	Medium to very coarse sand, some very fine to fine gravel, trace of fragments.
39.6 - 42.7	(130.0 - 140.0)	Very fine to medium gravel and coarse sand, some brown silt and clay, trace of medium sand.
42.7 - 54.9	(140.0 - 180.0)	Medium to very coarse sand, some very fine to fine gravel and fragments, trace of fine sand.

MP #7
Date Drilled: August 24, 1978

Depth		Description[a]
0 - 3.0 m	(0 - 10.0 ft)	Coarse to very coarse sand and very fine gravel, trace of brown clay and silt.
3.0 - 6.1	(10.0 - 20.0)	Coarse to very coarse sand and very fine gravel, trace of brown clay and silt.

[a] Colors where not indicated variegated grey to brown.

WELL LOGS - BALEFILL
(Continued)

MP #4

45.7 - 48.8	(150.0 - 160.0)	Fine to coarse sand, some fine to medium gravel.
48.8 - 61.0	(160.0 - 200.0)	Medium to coarse sand, some fine sand, trace of very fine to fine gravel.

MP #5
Date Drilled: May 10, 1978

Depth		Description
0 - 1.2 m	(0 - 4.0 ft)	Top soil.
1.2 - 12.8	(4.0 - 42.0)	Gravel.
12.8 - 13.7	(42.0 - 45.0)	Clay.
13.7 - 18.3	(45.0 - 60.0)	Gravel.
18.3 - 19.5	(60.0 - 64.0)	Clay.
19.5 - 31.4	(64.0 - 103.0)	Gravel.
31.4 - 37.5	(103.0 - 123.0)	Clay.
37.5 - 49.7	(123.0 - 163.0)	Fine sand.
49.7 - 51.8	(163.0 - 170.0)	Clay.
51.8 - 64.0	(170.0 - 210.0)	Fine, dirty sand.
64.0 - 68.6	(210.0 - 225.0)	Sandstone.
68.6 - 69.2	(225.0 - 227.0)	Limestone.

MP #6
Date Drilled: August 22, 1978

Depth		Description[a]
0 - 3.0 m	(0 - 10.0 ft)	Grey-brown clay and silt, some fine to coarse sand, and refuse, fill.
3.0 - 6.1	(10.0 - 20.0)	Light brown, fine to medium sand, clean.
6.1 - 12.2	(20.0 - 40.0)	Coarse to very coarse sand, some fine to medium sand.

[a] Colors where not indicated variegated grey to brown.

WELL LOGS - BALEFILL
(Continued)

MP #4
Date Drilled: August 17, 1978

Depth		Description[a]
0 - 3.0 m	(0 - 10.0 ft)	Brown fine gravel, some silt and medium to coarse sand.
3.0 - 6.1	(10.0 - 20.0)	Light brown silt and very fine gravel, some fine to coarse sand.
6.1 - 9.1	(20.0 - 30.0)	Very fine to fine gravel, some silt and fine to coarse sand and fragments.
9.1 - 12.2	(30.0 - 40.0)	Medium to very coarse sand, some very fine to fine gravel.
12.2 - 18.3	(40.0 - 60.0)	Very fine to fine gravel and medium to coarse sand.
18.3 - 24.4	(60.0 - 80.0)	Medium to very coarse sand, some very fine to fine gravel and fine sand.
24.4 - 27.4	(80.0 - 90.0)	Fine to medium gravel, some medium to coarse sand.
27.4 - 30.5	(90.0 - 100.0)	Coarse to very coarse sand, some medium sand and very fine gravel, trace of small fragments.
30.5 - 33.5	(100.0 - 110.0)	Fine to coarse gravel and medium to very coarse sand.
33.5 - 36.6	(110.0 - 120.0)	Medium to coarse sand, some very fine to fine gravel and fragments.
36.6 - 39.6	(120.0 - 130.0)	Brown clay, silt and fine to medium sand, trace of fragments.
39.6 - 45.7	(130.0 - 150.0)	Fine to coarse sand, trace of very fine gravel and fragments.

[a] Colors where not indicated variegated grey to brown.

WELL LOGS - BALEFILL
(Continued)

MP #7

6.1 - 12.2	(20.0 - 40.0)	Medium to very coarse sand.
12.2 - 18.3	(40.0 - 60.0)	Coarse to very coarse sand and very fine to fine gravel, trace of brown silt and clay.
18.3 - 21.3	(60.0 - 70.0)	Coarse to very coarse sand and very fine to fine gravel, some medium gravel, brown silt and clay.
21.3 - 27.4	(70.0 - 90.0)	Medium to very coarse sand.
27.4 - 30.5	(90.0 - 100.0)	Brown clay, some fine to coarse sand, little fine to medium gravel.
30.5 - 36.6	(100.0 - 120.0)	Medium to coarse sand, trace of very fine to fine gravel.
36.6 - 45.7	(120.0 - 150.0)	Medium to coarse sand, trace of fine sand.

WELL LOGS - MILLFILL

MP #1
Date Drilled: June 20, 1974

Depth		Description
0 - 0.6 m	(0 - 2.0 ft)	Fill and loam.
0.6 - 1.8	(2.0 - 6.0)	Yellow clay.
1.8 - 2.7	(6.0 - 9.0)	Grey clay and gravel.
2.7 - 4.0	(9.0 - 13.0)	Fine sand.
4.0 - 6.4	(13.0 - 21.0)	Fine to coarse brown sand.
6.4 - 8.2	(21.0 - 27.0)	Sand, stones and clay.
8.2 - 9.1	(27.0 - 30.0)	Sand, gravel, water.
9.1 - 11.0	(30.0 - 36.0)	Soft, grey clay.
11.0 - 11.9	(36.0 - 39.0)	Sand, gravel, clay
11.9 - 12.2	(39.0 - 40.0)	Fine soft sand, silt with gravel, water.
12.2 - 13.1	(40.0 - 43.0)	Compact soft sand, trace of gravel.
13.1 - 13.4	(43.0 - 44.0)	Coarse sand, gravel, water.

MP #4
Date Drilled: April 30, 1974

Depth		Description
0 - 1.5 m	(0 - 5.0 ft)	Brown moist fine sand and fine to coarse gravel.
1.5 - 6.1	(5.0 - 20.0)	Grey moist fine sand and fine to coarse gravel; boulders.

MP #5
Date Drilled: April 30, 1974

Depth		Description
0 - 6.1 m	(0 - 20.0 ft)	Brown moist fine sandy silt and fine to coarse gravel; boulders.

WELL LOGS - MILLFILL
(Continued)

MP #6
Date Drilled: November 28, 1978

Depth	Description
0 - 1.8 m (0 - 6.0 ft)	Grey medium gravel and brown soil.
1.8 - 6.1 (6.0 - 20.0)	Brown fine sand and silt, minor clay and medium gravel.
6.1 - 7.6 (20.0 - 25.0)	Brown fine to medium sand, minor clay. Damp.
7.6 - 10.7 (25.0 - 35.0)	Grey to brown, fine to coarse sand, minor clay. Wet.

MP #7
Date Drilled: November 28, 1978

Depth	Description
0 - 1.8 m (0 - 6.0 ft)	Grey medium gravel and boulders, minor soil.
1.8 - 6.1 (6.0 - 20.0)	Grey fine to medium gravel, minor clay, silt and boulders. Damp at 4.5 m (15 ft).
6.1 - 9.1 (20.0 - 30.0)	Medium to coarse gravel, minor clay and silt. Wet.

Well Logs for MP #2 were unavailable.

WELL LOGS - STRIP MINE LANDFILL

MP #5
Date Drilled: July 19, 1978

Depth	Description
0 - 2.4 m (0 - 8.0 ft)	Weathered brown shale with some clay layers.
2.4 - 5.8 (8.0 - 19.0)	Alternating beds of clay and decomposed shale.
5.8 - 10.7 (19.0 - 35.0)	Brown shale.
10.7 - 19.8 (35.0 - 65.0)	Grey shale.
19.8 - 21.9 (65.0 - 72.0)	Black shale (carboniferous).
21.9 - 25.3 (72.0 - 83.0)	Grey shale.
25.3 - 25.9 (83.0 - 85.0)	Coal.
25.9 - 37.2 (85.0 - 122.0)	Grey shale.
37.2 - 38.1 (122.0 - 135.0)	Coal.
38.1 - 38.4 (125.0 - 126.0)	Clay and grey shale.
38.4 - 48.8 (126.0 - 160.0)	Grey shale.

MP #6
Date Drilled: July 19, 1978

Depth	Description
0 - 1.5 m (0 - 5.0 ft)	Brown sandy shale (backfill).
1.5 - 1.7 (5.0 - 5.5)	Coal, water at 1.5 m (5.0 ft).
5.5 - 10.7 (5.5 - 35.0)	Brown shale.

MP #7
Date Drilled: July 19, 1978

Depth	Description
0 - 3.0 m (0 - 10.0 ft)	Alternating fill and brown shale.
3.0 - 4.6 (10.0 - 15.0)	Brown shale.
4.6 - 5.2 (15.0 - 17.0)	Coal.
5.2 - 7.6 (17.0 - 25.0)	Grey shale.
7.6 - 16.8 (25.0 - 55.0)	Brown shale.
16.8 - 17.4 (55.0 - 57.0)	Coal.
17.4 - 24.4 (57.0 - 80.0)	Grey shale, water at 18.3 m (60.0 ft).

WELL LOGS - PERMITTED SANITARY LANDFILL

MP #1
Date Drilled: January 1975

Depth	Description
0 - 16.5 m (0 - 54.0 ft)	Glacial till, grey to brown clay, silt, weathered shale, cobbles, boulders.
16.5 - 17.1 (54.0 - 56.0)	Weathered shale.
17.1 - 20.1 (56.0 - 66.0)	Grey shale, layered, varying in hardness, and color (grey) to bedrock.

MP #2
Date Drilled: January 1975

Depth	Description
0 - 15.5 m (0 - 51.0 ft)	Glacial till, grey to brown clay, silt, weathered shale, cobbles, boulders.
15.5 - 30.5 (51.0 - 100.0)	Grey shale, layered, varying in hardness and color (grey) to bedrock.

MP #3
Date Drilled: January 1975

Depth	Description
0 - 1.2 m (0 - 4.0 ft)	Cover material and solid waste.
1.2 - 6.1 (4.0 - 20.0)	Glacial till, grey to brown clay, silt, weathered shale, cobbles, boulders.
6.1 - 19.2 (20.0 - 63.0)	Grey shale, layered, varying in hardness and color (grey) to bedrock.

WELL LOGS - PERMITTED SANITARY LANDFILL
(Continued)

MP #4
Date Drilled: November 1977

Depth		Description
0 - 1.1 m	(0 - 3.5 ft)	Glacial till, grey brown shaley clay.
1.1 - 31.1	(3.5 - 102.0)	Grey shale, layered, varying in hardness and color (grey) to bedrock.

MP #5
Date Drilled: November 1977

Depth		Description
0 - .6 m	(0 - 2.0 ft)	Cover material, brown grey clay and small shale fragments.
.6 - .8	(2.0 - 2.5)	Fill wood fragments.
.8 - 13.3	(2.5 - 43.5)	Glacial till, grey to brown clay, silt, weathered shale, cobbles, boulders.
13.3 - 31.1	(43.5 - 102.0)	Grey shale, layered, varying in hardness and color (grey) to bedrock.

MP #6
Date Drilled: November 1977

Depth		Description
0 - 19.2 m	(0 - 63.0 ft)	Glacial till, grey to brown clay, silt, weathered shale, cobbles, boulders.
19.2 - 20.7	(63.0 - 68.0)	Grey shale, bedrock.

Well logs for MP #9 and #10 were unavailable.

APPENDIX B

GRAIN SIZE DISTRIBUTION CURVES

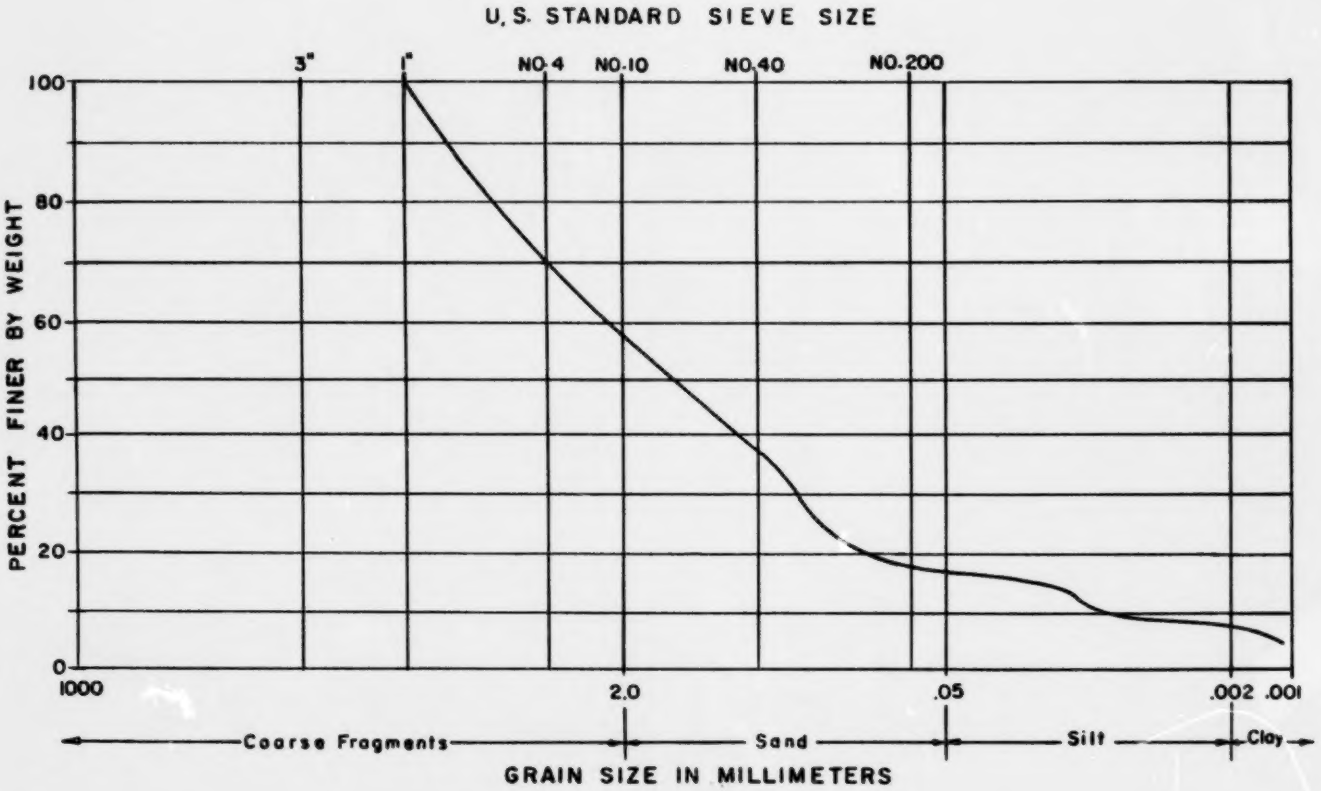


Figure B-1. Hillfill, MP #10 - Outwash 2.6 - 4.6 m
(8.5 - 15.0 ft)

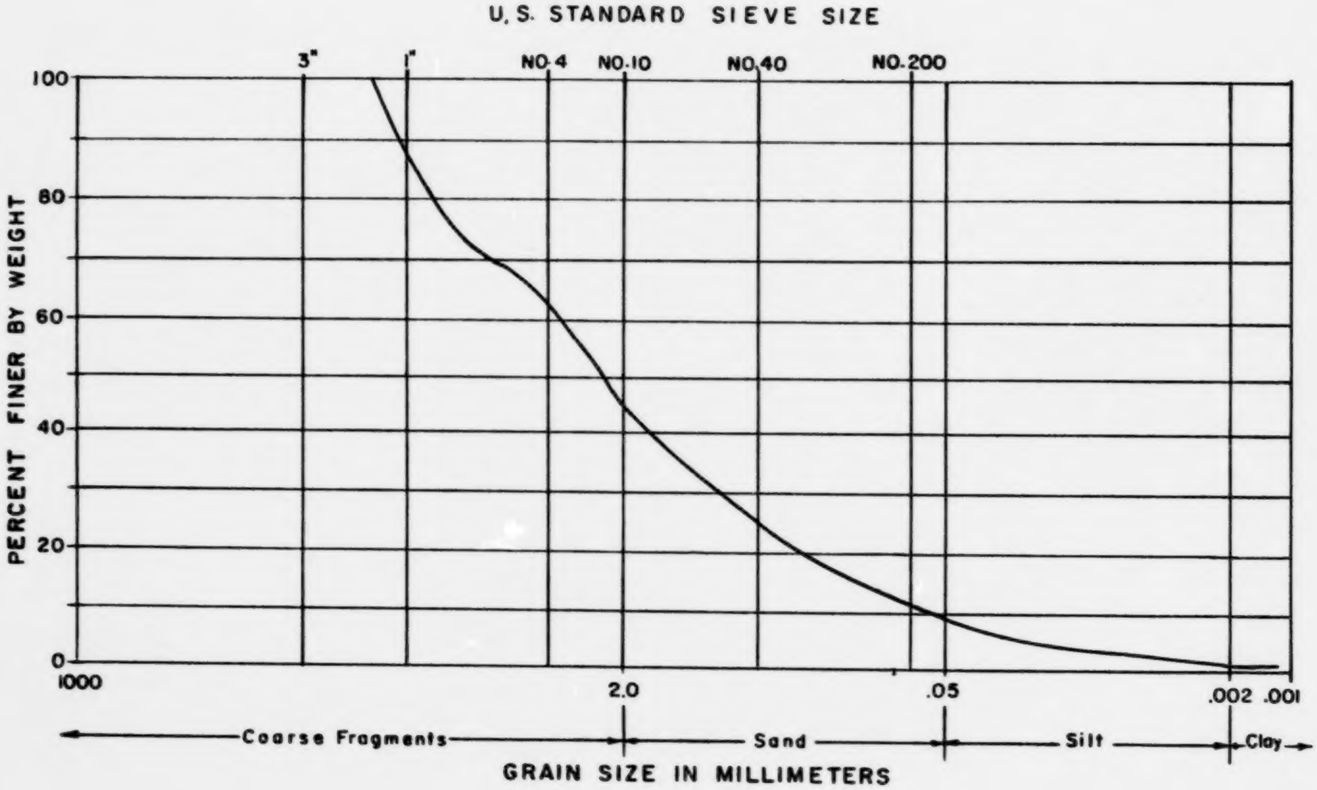


Figure B-2. Hillfill, MP #10 - Outwash 4.1 - 6.1 m
(13.5 - 20.0 ft)

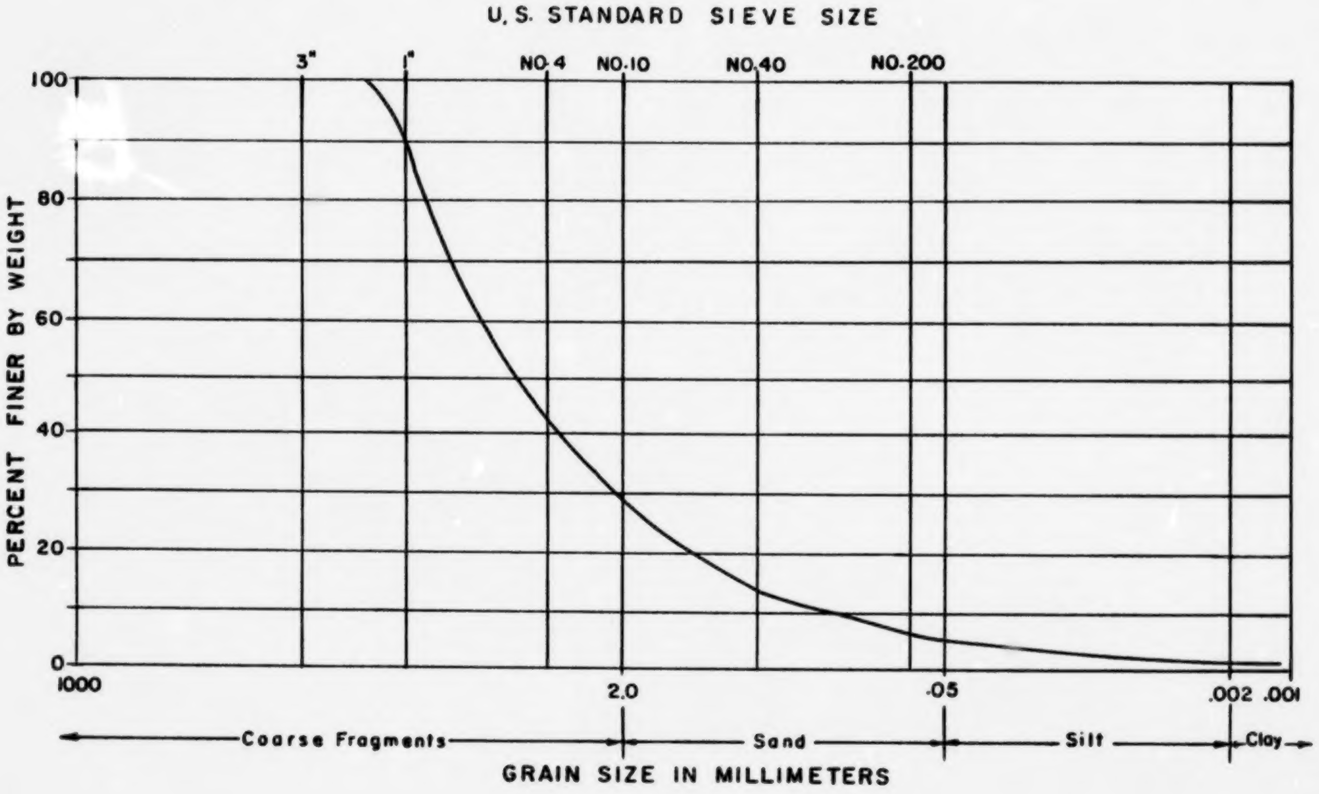


Figure B-3. Hillfill, MP #10 - Outwash 7.2 - 7.6 m
(23.5 - 25.0 ft)

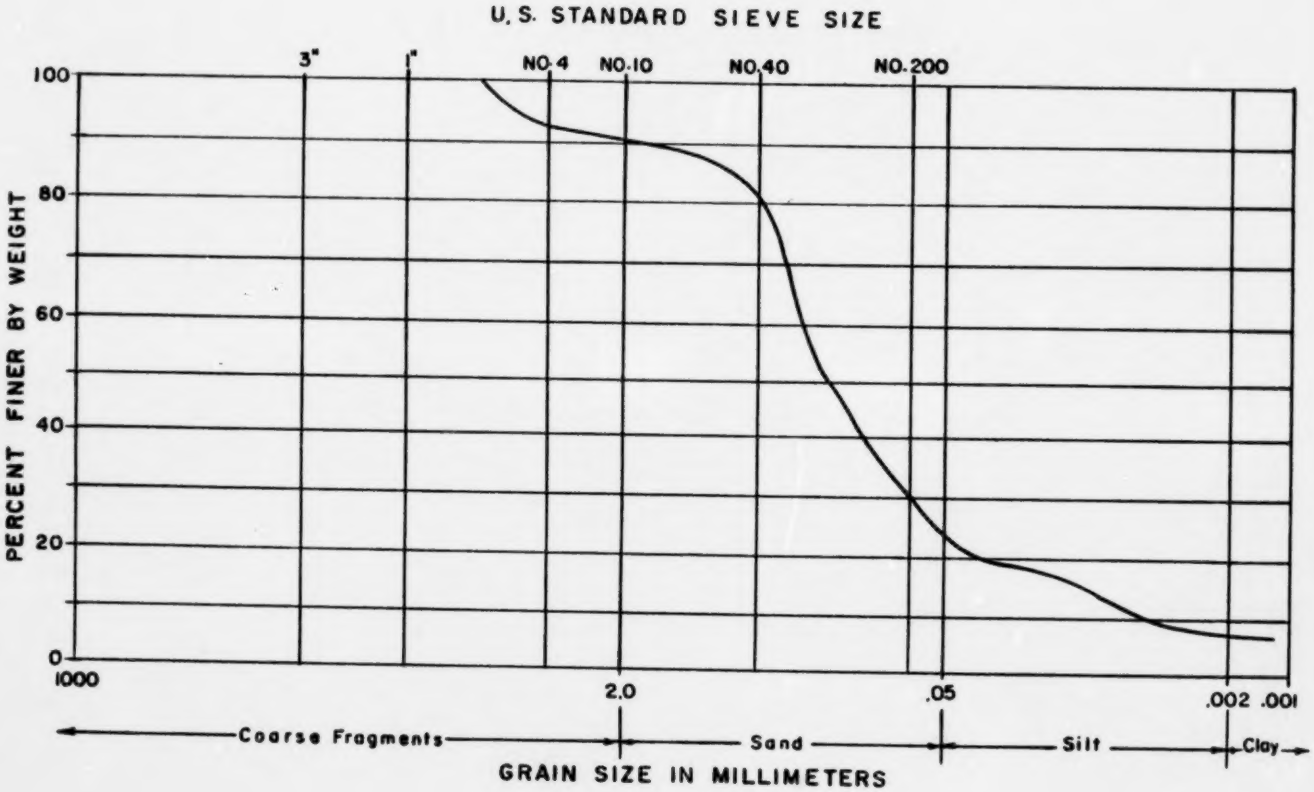


Figure B-4. Hillfill, MP #10 - Loess 1.1 - 1.5 m
(3.5 - 5.0 ft)

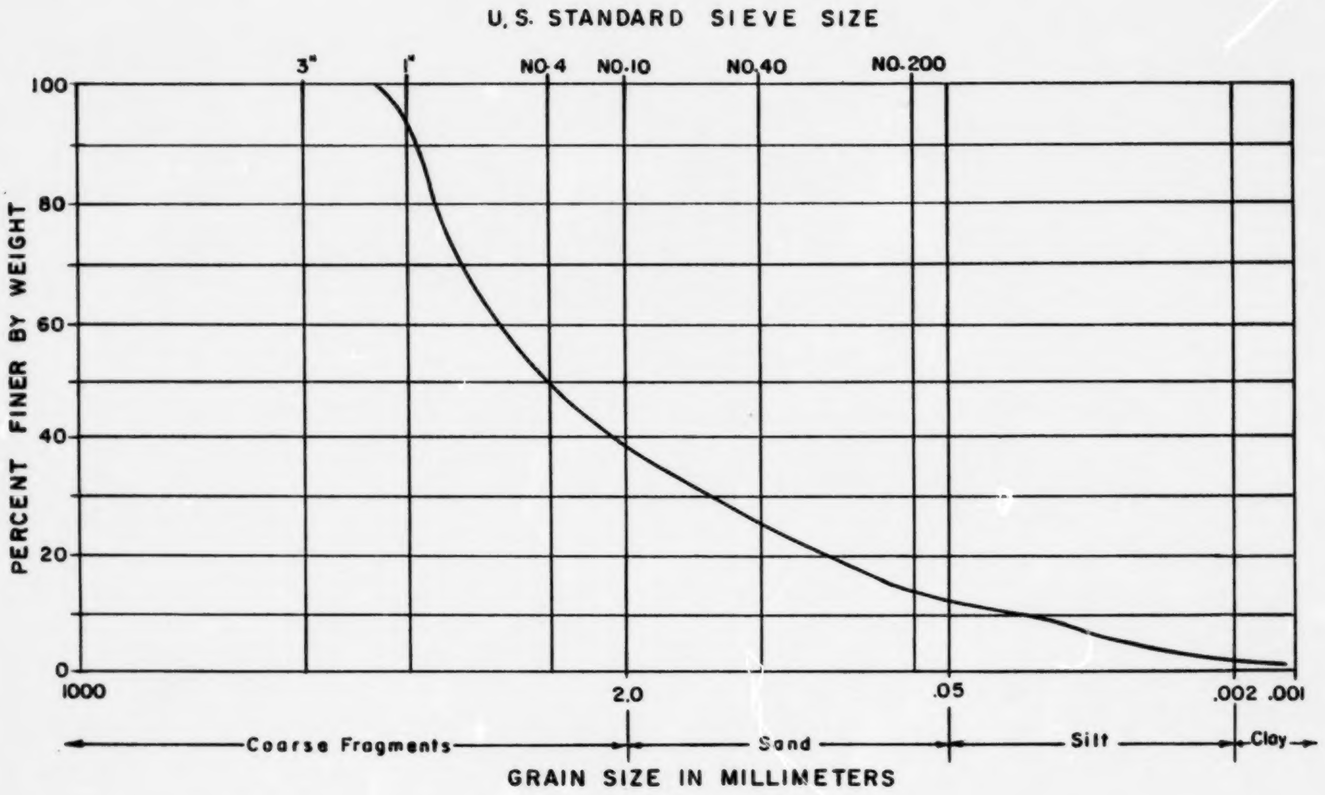


Figure B-5. Hillfill, MP #12 - Outwash 2.6 - 4.6 m (8.5 - 15.0 ft)

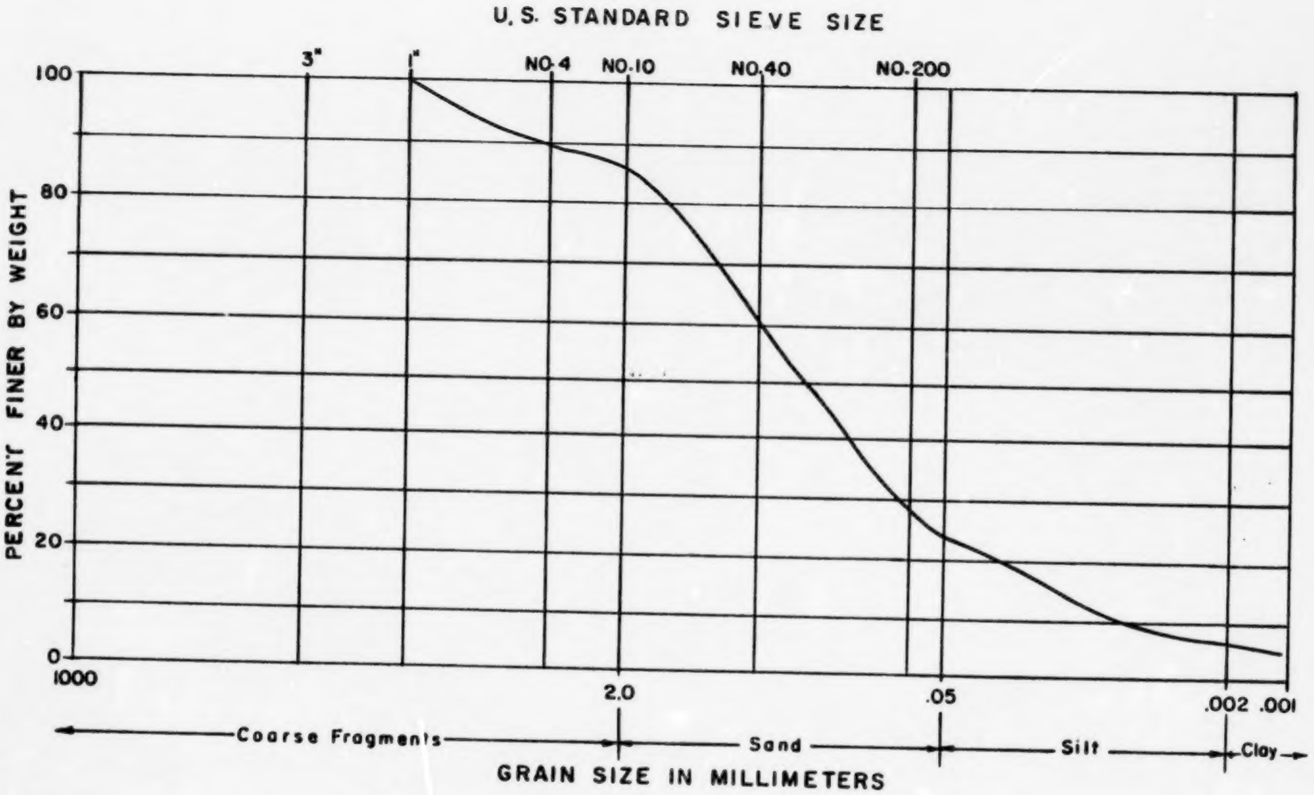


Figure B-6. Balefill, MP #2 - Some till, sand, and gravel
2.1 - 6.4 m
(7.0 - 21.0 ft)

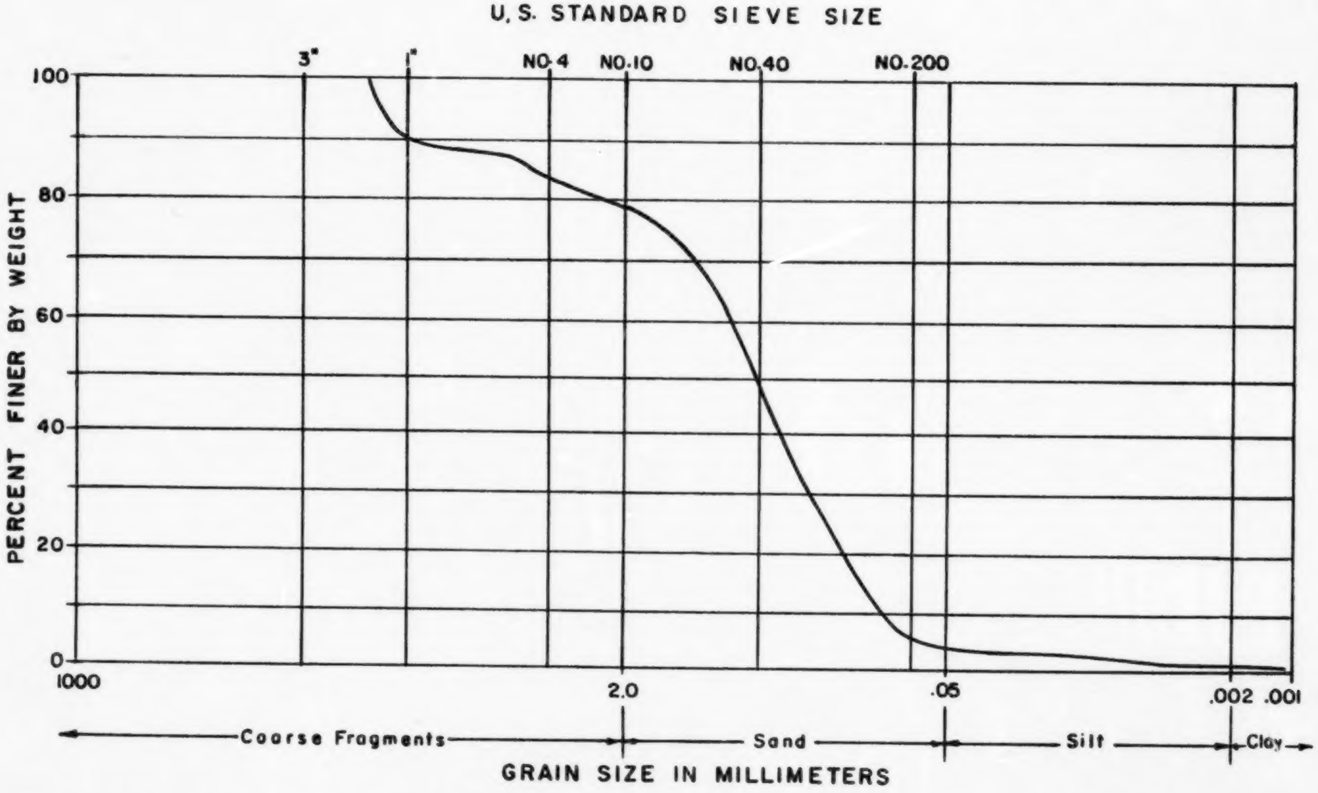


Figure B-7. Balefill, MP #2 - Sand and gravel 7.5 - 12.5 m
(24.5 - 41.0 ft)

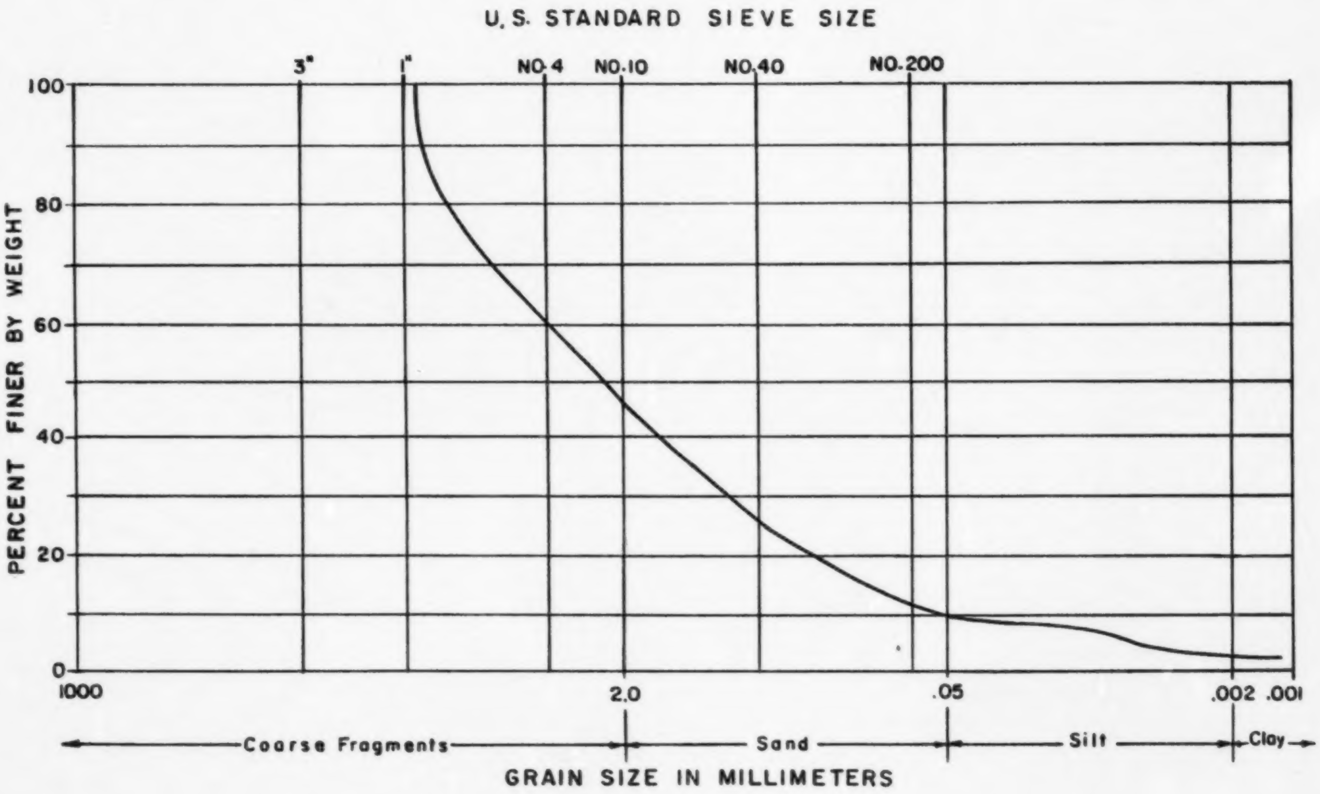


Figure B-8. Balefill, MP #2 - Sand and gravel 13.6 - 14.0 m
(44.5 - 46.0 ft)

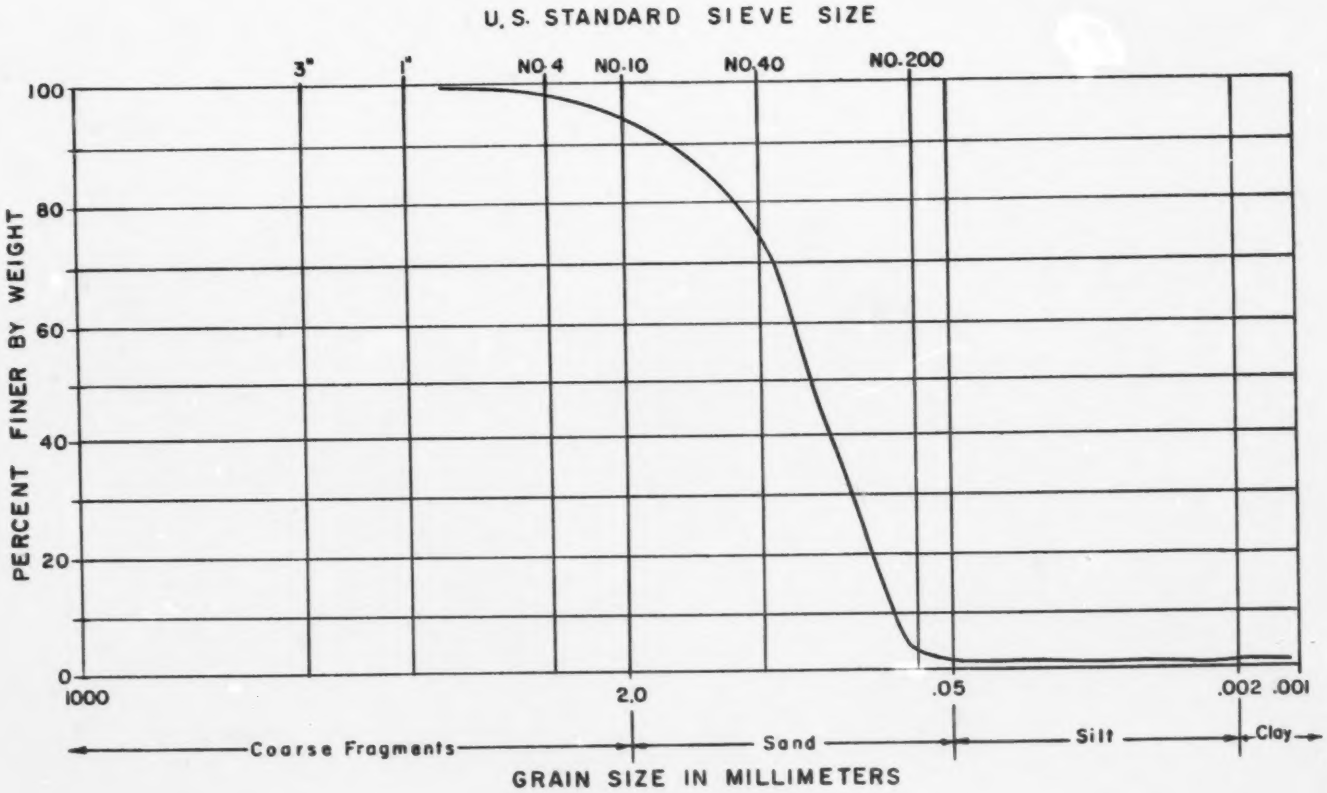


Figure B-9. Balefill, MP #2 - Sand and gravel 15.1 - 15.5 m
(49.5 - 51.0 ft)

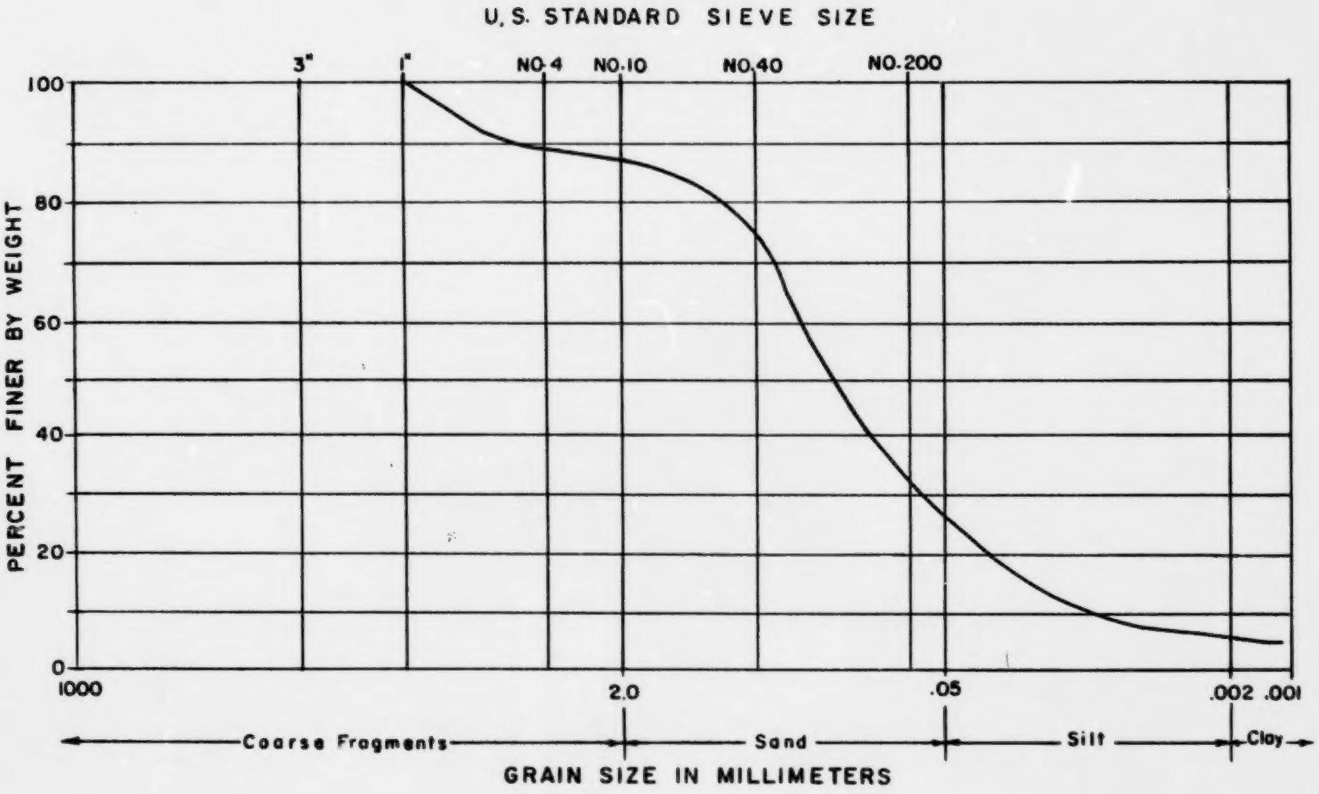


Figure B-10. Millfill, MP #6 - Outwash 3.0 - 10.7 m
(10.0 - 35.0 ft)

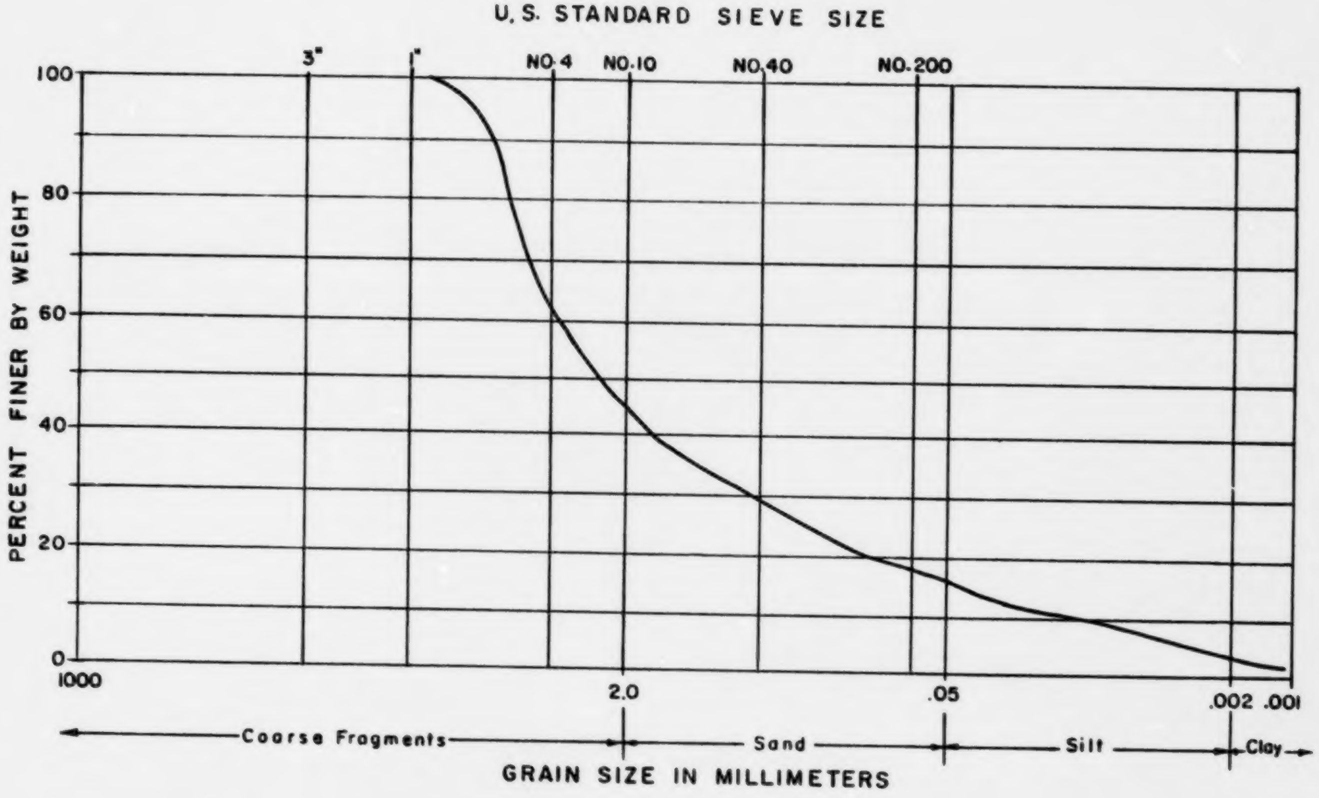


Figure B-11. Millfill, MP #7 - Outwash 3.0 - 6.1 m (10.0 - 20.0 ft)

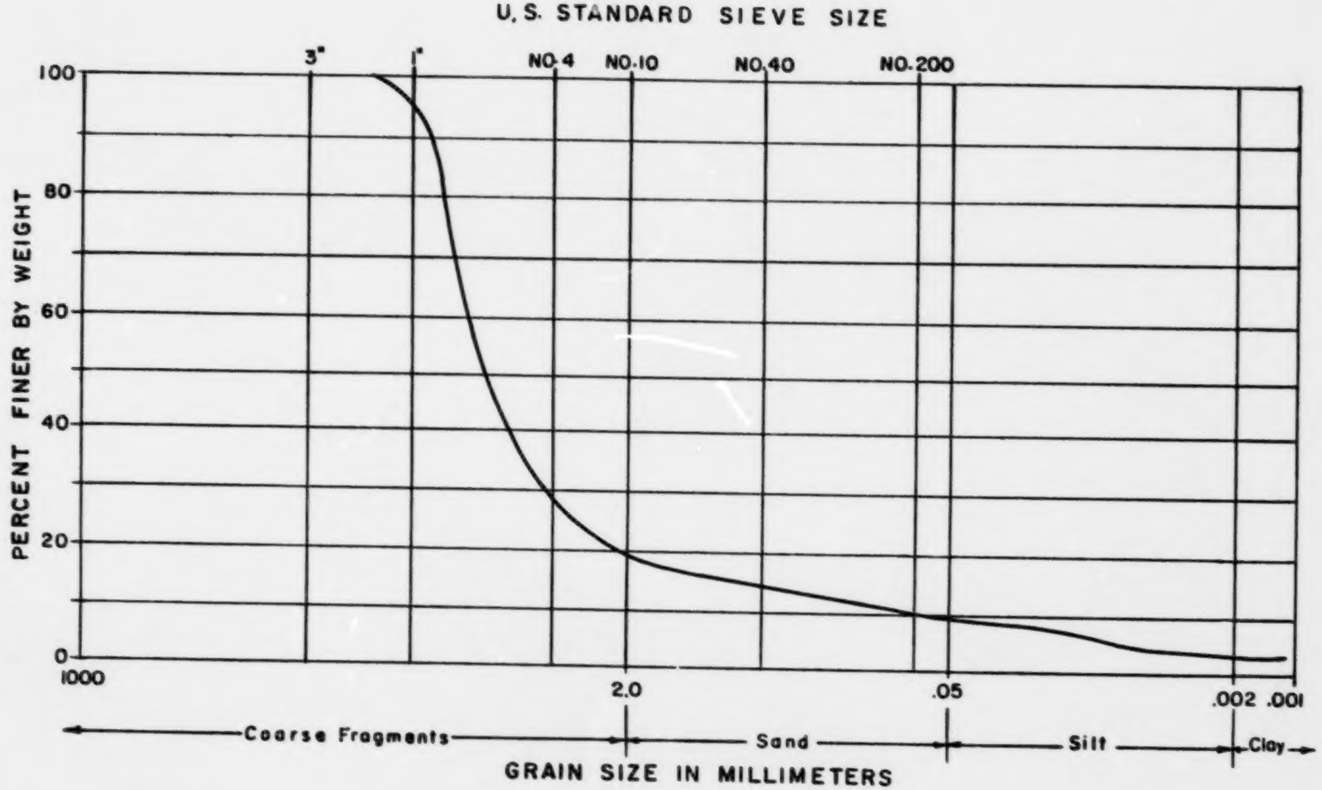


Figure B-12. Millfill, MP #7 - Outwash 7.6 - 9.1 m
(25.0 - 30.0 ft)

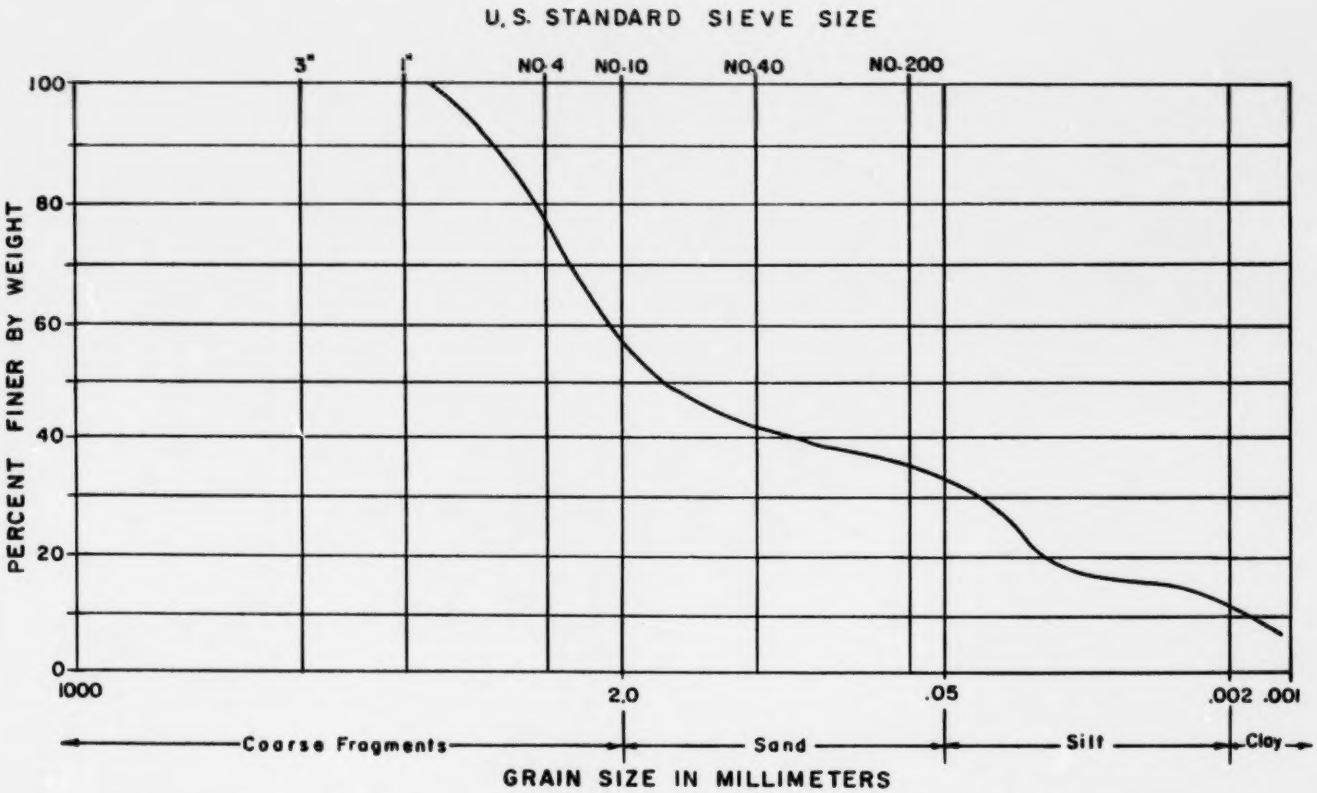


Figure B-13. Permitted Sanitary Landfill, MP #6 - Glacial Till
0.3 - 1.5 m
(1.0 - 5.0 ft)

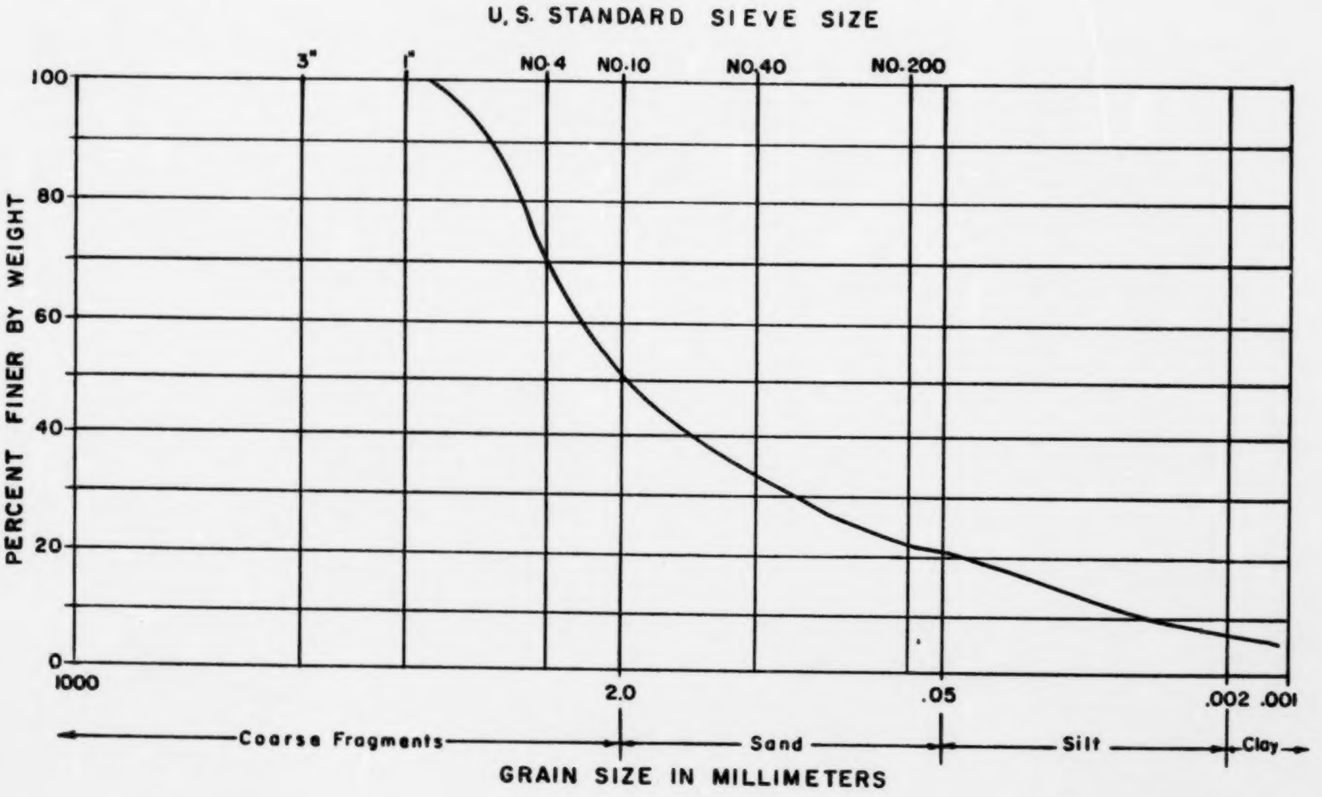


Figure B-14. Permitted Sanitary Landfill, MP #6 - Glacial Till
3.0 - 6.1 m
(10.0 - 20.0 ft)

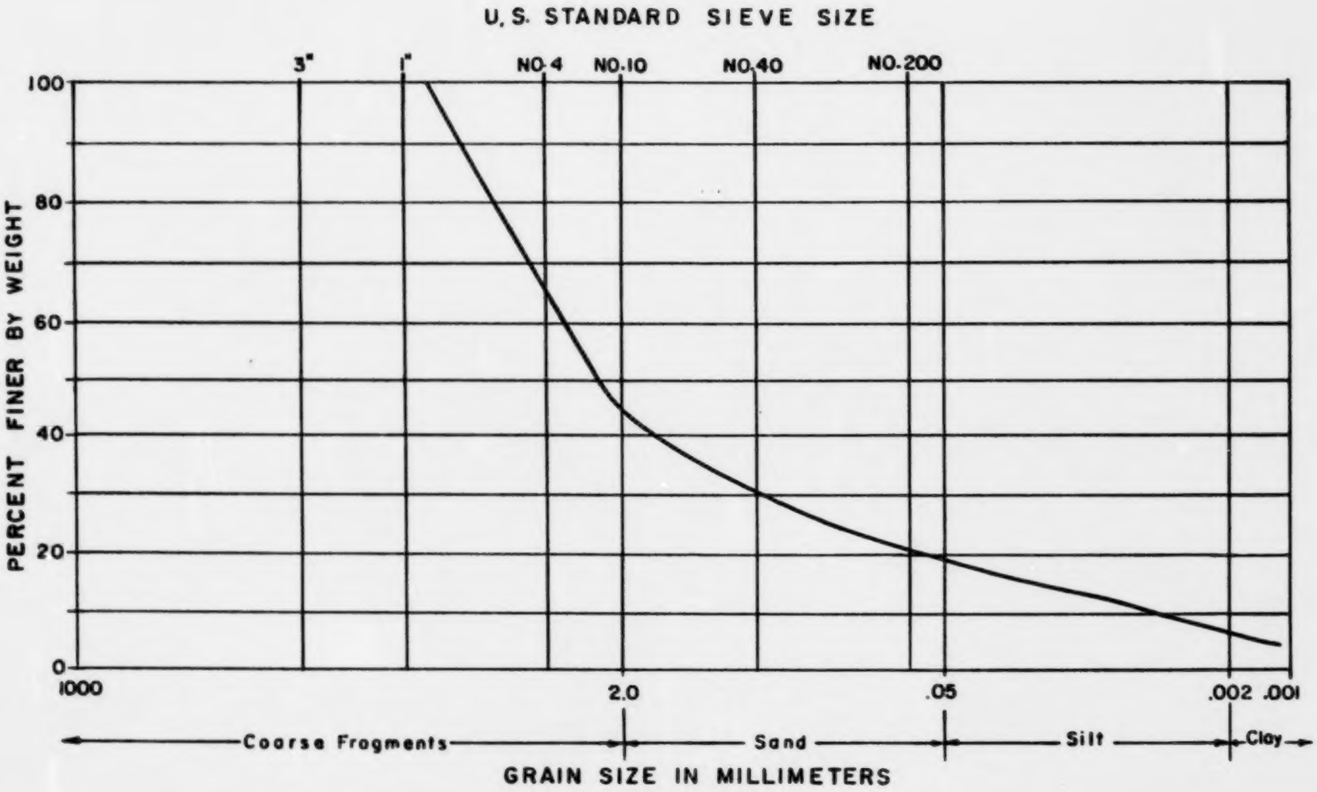


Figure B-15. Permitted Sanitary Landfill, MP #6 - Glacial Till
7.6 - 10.7 m
(25.0 - 35.0 ft)

APPENDIX C

WATER ELEVATIONS

Water Elevations from Monitoring Points - Hillfill[a, b]

MP #	Date	Depth to Water (TOC)	Elevation Water Table
1[c]	5/78	7.62 (25.00)	213.04 (698.95)
	11/78	7.92 (25.98)	212.74 (697.97)
	1/79	7.84 (25.72)	212.82 (698.23)
	4/79	6.79 (22.27)	213.87 (701.68)
	7/79	7.78 (25.54)	212.88 (698.41)
	Average	7.59 (24.90)	213.07 (699.05)
2[d]	5/78	14.23 (46.70)	230.73 (757.00)
	11/78	14.33 (47.00)	230.64 (756.70)
	1/79	14.11 (46.30)	230.86 (757.40)
	4/79	14.05 (46.10)	230.92 (757.60)
	7/79	14.04 (46.05)	230.93 (757.65)
	Average	14.15 (46.43)	230.82 (757.27)
3[e]	5/78	6.22 (20.40)	214.45 (703.57)
	11/78	6.84 (22.43)	213.83 (701.54)
	1/79	6.71 (22.00)	213.96 (701.97)
	4/79	5.26 (17.25)	215.41 (706.72)
	7/79	6.22 (20.41)	214.45 (703.56)
	Average	6.25 (20.50)	214.42 (703.47)
4[f]	5/78	5.39 (17.70)	215.27 (706.25)
	11/78	6.55 (21.48)	214.11 (702.47)
	1/79	6.43 (21.10)	214.23 (702.85)
	4/79	4.97 (16.30)	215.69 (707.65)
	7/79	5.98 (19.62)	214.68 (704.33)
	Average	5.86 (19.24)	214.80 (704.71)
5[g]	5/78	3.51 (11.50)	215.94 (708.45)
	11/78	3.93 (12.90)	215.51 (707.05)
	1/79	3.74 (12.28)	215.70 (707.67)
	4/79	3.41 (11.20)	216.03 (708.75)
	7/79	4.11 (13.50)	215.33 (706.45)
	Average	3.74 (12.28)	215.70 (707.67)

[a] All data in meters (feet).

[b] No data available for MP #11, 13, 15.

[c] Elevation top of casing (TOC) 220.66 m (723.95 ft)

[d] Elevation top of casing (TOC) 244.97 m (803.70 ft)

[e] Elevation top of casing (TOC) 220.67 m (723.97 ft)

[f] Elevation top of casing (TOC) 220.66 m (723.95 ft)

[g] Elevation top of casing (TOC) 219.44 m (719.95 ft)

Water Elevations from Monitoring Points - Hillfill[a, b] (Cont.)

MP#	Date	Depth to Water (TOC)		Elevation Water Table	
6[h]	5/78	3.54	(11.60)	215.93	(708.44)
	11/78	3.96	(13.00)	215.51	(707.04)
	Average	3.75	(12.30)	215.72	(707.74)
9[i]	5/78	1.49	(4.90)	215.07	(705.60)
	11/78	2.59	(8.50)	213.97	(702.00)
	1/79	2.26	(7.40)	214.30	(703.10)
	4/79	1.59	(5.21)	214.97	(705.29)
	7/79	2.40	(7.88)	214.16	(702.62)
	Average	2.07	(6.78)	214.49	(703.72)
10[j]	11/78	5.41	(17.75)	210.81	(691.65)
	1/79	5.17	(16.97)	211.05	(692.43)
	4/79	5.09	(16.70)	211.13	(692.70)
	7/79	5.04	(16.52)	211.19	(692.88)
	Average	5.18	(16.99)	211.05	(692.41)
12[k]	11/78	1.75	(5.73)	214.36	(703.27)
	1/79	1.73	(5.67)	214.37	(703.33)
	4/79	1.53	(5.01)	214.58	(703.99)
	7/79	2.03	(6.65)	214.08	(702.35)
	Average	1.76	(5.77)	214.34	(703.23)

[h] Elevation top of casing (TOC) 219.47 m (720.04 ft)

[i] Elevation top of casing (TOC) 216.56 m (710.50 ft)

[j] Elevation top of casing (TOC) 216.23 m (709.40 ft)

[k] Elevation top of casing (TOC) 216.10 m (709.00 ft)

Water Elevations from Monitoring Points - Balefill[a, b]

MP #	Date	Depth to Water (TOC)	Elevation Water Table
2[c]	8/78	51.97 (170.50)	222.98 (731.57)
	11/78	51.24 (168.12)	223.71 (733.95)
	1/79	51.25 (168.15)	223.70 (733.92)
	4/79	51.16 (167.85)	223.79 (734.22)
	7/79	51.08 (167.60)	223.87 (734.47)
	Average	51.34 (168.44)	223.61 (733.63)
4[d]	8/78	53.22 (174.60)	223.23 (732.37)
	11/78	52.82 (173.30)	223.62 (733.67)
	1/79	52.74 (173.02)	223.71 (733.95)
	4/79	52.76 (173.10)	223.68 (733.87)
	7/79	52.65 (172.72)	223.80 (734.25)
	Average	52.84 (173.35)	223.61 (733.62)
6[e]	8/78	45.34 (148.75)	224.67 (737.10)
	11/78	44.71 (146.70)	225.29 (739.15)
	1/79	44.69 (146.61)	225.32 (739.24)
	4/79	44.60 (146.32)	225.41 (739.53)
	7/79	44.52 (146.07)	225.48 (739.78)
	Average	44.77 (146.89)	225.24 (738.96)
7[f]	8/78	34.75 (114.00)	233.50 (766.09)
	11/78	33.51 (109.95)	234.74 (770.14)
	1/79	33.38 (109.50)	234.88 (770.59)
	4/79	33.45 (109.75)	234.80 (770.34)
	7/79	33.36 (109.45)	234.89 (770.64)
	Average	33.69 (110.53)	234.56 (769.56)

---

[a] All data in meters (feet).

[b] No data available for MP #5.

[c] Elevation top of casing (TOC) 274.95 m (902.07 ft)

[d] Elevation top of casing (TOC) 276.44 m (906.97 ft)

[e] Elevation top of casing (TOC) 270.00 m (885.85 ft)

[f] Elevation top of casing (TOC) 268.25 m (880.09 ft)

Water Elevations from Monitoring Points - Millfill[a, b]

MP #	Date	Depth to Water (TOC)	Elevation Water Table
2[c]	12/78	3.29 (10.80)	243.73 (799.63)
	2/79	2.50 (8.20)	241.53 (792.43)
	5/79	2.28 (7.49)	244.80 (803.14)
	8/79	3.12 (10.25)	243.96 (800.38)
	Average	2.80 (9.19)	243.50 (798.90)
4[d]	12/78	1.57 (5.15)	264.28 (867.05)
	2/79	1.40 (4.60)	264.44 (867.60)
	5/79	1.58 (5.20)	264.26 (867.00)
	8/79	1.42 (4.65)	264.43 (867.55)
	Average	1.49 (4.90)	264.35 (867.30)
6[e]	12/78	7.32 (24.00)	246.98 (810.30)
	2/79	6.78 (22.25)	247.51 (812.05)
	5/79	6.17 (20.23)	248.13 (814.07)
	8/79	6.90 (22.65)	247.39 (811.65)
	Average	6.79 (22.28)	247.50 (812.02)
7[f]	12/78	5.52 (18.10)	243.11 (797.60)
	2/79	4.50 (14.75)	244.13 (800.95)
	5/79	4.14 (13.58)	244.49 (802.12)
	8/79	5.22 (17.12)	243.41 (798.58)
	Average	4.84 (15.89)	243.78 (799.81)

[a] All data in meters (feet).
[b] No data available for MP #1, 5.
[c] Elevation top of casing (TOC) 247.08 m (810.63 ft)
[d] Elevation top of casing (TOC) 265.85 m (872.20 ft)
[e] Elevation top of casing (TOC) 254.29 m (834.30 ft)
[f] Elevation top of casing (TOC) 248.63 m (815.70 ft)

Water Elevations from Monitoring Points - Strip Mine Landfill[a]

MP #	Date	Depth to Water (TOC)	Elevation Water Table
5[b]	9/78	38.38 (125.92)	478.03 (1568.33)
	12/78	38.26 (125.53)	478.15 (1568.72)
	2/79	38.37 (125.90)	478.03 (1568.35)
	5/79	38.55 (126.47)	477.86 (1567.78)
	8/79	38.40 (126.00)	478.00 (1568.25)
	Average	38.39 (125.96)	478.01 (1568.29)
6[c]	8/78	1.73 (5.68)	485.63 (1593.27)
	12/78	1.59 (5.23)	485.77 (1593.72)
	2/79	1.84 (6.05)	485.52 (1592.90)
	5/79	1.61 (5.27)	485.75 (1593.68)
	8/79	1.54 (5.06)	485.82 (1593.89)
	Average	1.66 (5.46)	485.70 (1593.49)
7[d]	8/78	13.56 (44.50)	474.51 (1556.80)
	12/78	13.52 (44.36)	474.56 (1556.94)
	2/79	13.62 (44.70)	474.45 (1556.60)
	5/79	13.61 (44.66)	474.46 (1556.64)
	8/79	13.59 (44.60)	474.48 (1556.70)
	Average	13.58 (44.56)	474.49 (1556.74)

[a] All data in meters (feet).

[b] Elevation top of casing (TOC) 516.41 m (1694.25 ft)

[c] Elevation top of casing (TOC) 487.36 m (1598.95 ft)

[d] Elevation top of casing (TOC) 488.08 m (1601.30 ft)

Water Elevations from Monitoring Points - Permitted Sanitary Landfill[a]

MP #	Date	Depth to Water (TOC)	Elevation Water Table
1[b]	12/78	14.43 (47.35)	319.54 (1048.35)
	2/79	14.39 (47.20)	319.58 (1048.50)
	5/79	14.43 (47.33)	319.54 (1048.37)
	8/79	14.52 (47.65)	319.45 (1048.05)
	Average	14.44 (47.38)	319.53 (1048.32)
2[c]	12/78	15.61 (51.20)	323.47 (1061.25)
	2/79	15.13 (49.65)	323.94 (1062.80)
	5/79	15.22 (49.95)	323.85 (1062.50)
	8/79	15.49 (50.82)	323.58 (1061.63)
	Average	15.36 (50.41)	323.71 (1062.05)
3[d]	12/78	13.35 (43.80)	328.80 (1078.75)
	2/79	13.21 (43.35)	328.94 (1079.20)
	5/79	13.26 (43.51)	328.89 (1079.04)
	8/79	13.44 (44.08)	328.72 (1078.47)
	Average	13.32 (43.69)	328.84 (1078.87)
4[e]	12/78	6.34 (20.80)	342.92 (1125.05)
	2/79	4.48 (14.70)	344.77 (1131.15)
	5/79	4.30 (14.10)	344.96 (1131.75)
	8/79	5.13 (16.83)	344.13 (1129.02)
	Average	5.06 (16.61)	344.19 (1129.24)

[a] All data in meters (feet).
[b] Elevation top of casing (TOC) 333.97 m (1095.70 ft)
[c] Elevation top of casing (TOC) 339.07 m (1112.45 ft)
[d] Elevation top of casing (TOC) 342.15 m (1122.55 ft)
[e] Elevation top of casing (TOC) 349.26 m (1145.85 ft)

Water Elevations from
Monitoring Points - Permitted Sanitary Landfill (Cont.)

MP #	Date	Depth to Water (TOC)		Elevation Water Table	
5[f]	12/78	22.46	(73.70)	317.54	(1041.80)
	2/79	17.10	(56.10)	322.91	(1059.40)
	5/79	17.03	(55.88)	322.97	(1059.62)
	8/79	17.36	(56.95)	322.65	(1058.55)
	Average	18.49	(60.66)	321.52	(1054.84)
6[g]	12/78	12.60	(41.33)	325.64	(1068.37)
	2/79	12.34	(40.50)	325.89	(1069.20)
	5/79	12.42	(40.75)	325.82	(1068.95)
	8/79	12.80	(42.00)	325.43	(1067.70)
	Average	12.54	(41.15)	325.70	(1068.56)

---

[f] Elevation top of casing (TOC) 340.00 m (1115.50 ft)
[g] Elevation top of casing (TOC) 338.24 m (1109.70 ft)

APPENDIX D

HISTORICAL CHEMICAL ANALYSES

KEY TO APPENDIX D

TEMP	Temperature, expressed in degrees centigrade
PH	pH, expressed in pH units
ALK	Alkalinity, total, as $CaCO_3$ *
SO4	Sulfate
SC	Specific conductance, expressed in micromhos/centimeter
CL	Chloride
TOC	Total organic carbon
COD	Chemical oxygen demand
TS	Total solids
TDS	Total dissolved solids
NO3-N	Nitrate nitrogen
NH3-N	Ammonia nitrogen
PO4-P	Phosphate, total
TKN	Total Kjeldahl nitrogen
CU	Copper
FE	Iron, total
MN	Manganese
NA	Sodium
PB	Lead
ZN	Zinc
ACID-O	Organic acids, as acetic acid
BOD-5	Biological oxygen demand, 5 day
BOD-20	Biological oxygen demand, 20 day
IC	Inorganic carbon
TC	Total carbon
CN	Cyanide
COLOR	Color, expressed in Pt-Co units
HARD	Hardness
HEXSOL	Hexane solubles
NO2-N	Nitrite nitrogen
ALB-N	Albuminoid nitrogen
ORG-N	Organic nitrogen
OPO4-P	Orthophosphate
PHENOL	Phenols
SET S	Settleable solids, expressed in milliliters/liter
SS	Suspended solids

TURB	Turbidity, expressed in JTU
AG	Silver
AL	Aluminum
AS	Arsenic
B	Boron
BA	Barium
CA	Calcium
CD	Cadmium
CR	Chromium
CR+6	Chromium, hexavalent
F	Fluoride
HG	Mercury
K	Potassium
MG	Magnesium
NI	Nickel
S	Sulfide
SE	Selenium

* All analyses in milligrams/liter unless otherwise noted.
- Dashes indicate no data.
6/0/78 indicates that exact date of sampling is unknown.

```
                                                             HILLFILL
                                                                          MONITOR POINTS
PARAM     DATE          1        2        3        4        5        6        7        8        9       10       11       12       13       14       15

PH        3/17/69        -        -        -        -        -        -      8.2      7.9        -        -        -        -        -      8.2        -
          4/21/69        -        -        -        -        -        -      8.5      8.5        -        -        -        -        -      8.3        -
          6/25/69        -        -        -        -        -        -      8.3      8.4        -        -        -        -        -      8.3        -
          8/14/69        -        -        -        -        -        -      8.1      8.2        -        -        -        -        -      8.2        -
         10/13/69        -        -        -        -        -        -      8.0      8.0        -        -        -        -        -      7.8        -
         10/27/69        -        -        -        -        -        -      8.1      8.1        -        -        -        -        -      8.1        -
          6/29/70        -        -        -        -        -        -      8.3      8.4        -        -        -        -        -      8.3        -
          7/16/70        -        -        -        -        -        -      8.6      8.7        -        -        -        -        -      8.6        -
          3/ 9/71        -        -        -        -        -        -      8.2      8.3        -        -        -        -        -      8.1        -
          4/ 7/71        -        -        -        -        -        -      8.4      8.4        -        -        -        -        -      8.4        -
          7/14/71        -        -        -        -        -        -      8.6      8.6        -        -        -        -        -      8.6        -
# OBS                    -        -        -        -        -        -       11       11        -        -        -        -        -       11        -
MEAN                     -        -        -        -        -        -      8.3      8.3        -        -        -        -        -      8.3        -
STD DEV                  -        -        -        -        -        -       .2       .2        -        -        -        -        -       .2        -

ALK       2/ 0/69        -   3255.0        -        -        -        -        -        -        -        -        -        -        -        -        -
          8/26/74        -        -    252.0    672.0        -    948.0        -        -    912.0        -        -        -        -        -        -
# OBS                    -        1        1        1        -        1        -        -        1        -        -        -        -        -        -
MEAN                     -   3255.0    252.0    672.0        -    948.0        -        -    912.0        -        -        -        -        -        -
STD DEV                  -       .0       .0       .0        -       .0        -        -       .0        -        -        -        -        -        -

SO4       2/ 0/69        -    680.0        -        -        -        -        -        -        -        -        -        -        -        -        -
          8/26/74        -        -     80.0     78.0        -    220.0        -        -    260.0        -        -        -        -        -        -
# OBS                    -        1        1        1        -        1        -        -        1        -        -        -        -        -        -
MEAN                     -    680.0     80.0     78.0        -    220.0        -        -    260.0        -        -        -        -        -        -
STD DEV                  -       .0       .0       .0        -       .0        -        -       .0        -        -        -        -        -        -

CL        2/ 0/69        -   1497.0        -        -        -        -        -        -        -        -        -        -        -        -        -
          3/17/69        -        -        -        -        -        -    160.0    119.0        -        -        -        -        -    186.0        -
          4/21/69        -        -        -        -        -        -     73.0     48.0        -        -        -        -        -     70.0        -
          6/25/69        -        -        -        -        -        -     18.0     17.0        -        -        -        -        -     17.0        -
          8/14/69        -        -        -        -        -        -     18.0     22.0        -        -        -        -        -     36.0        -
         10/13/69        -        -        -        -        -        -     41.0     19.0        -        -        -        -        -     43.0        -
         10/27/69        -        -        -        -        -        -     53.0     45.0        -        -        -        -        -     72.0        -
          6/29/70        -        -        -        -        -        -     49.0     31.0        -        -        -        -        -     48.0        -
          7/16/70        -        -        -        -        -        -     52.0     33.0        -        -        -        -        -     52.0        -
          3/ 9/71        -        -        -        -        -        -     56.0     34.0        -        -        -        -        -     46.0        -
          4/ 7/71        -        -        -        -        -        -     62.0     37.0        -        -        -        -        -     60.0        -
          7/14/71        -        -        -        -        -        -     59.0     32.0        -        -        -        -        -     59.0        -
          6/13/72        -        -        -        -        -        -     48.0     48.0        -        -        -        -        -     30.0        -
          8/26/74        -        -      6.0     30.0        -    580.0        -        -     95.0        -        -        -        -        -        -
# OBS                    -        1        1        1        -        1       12       12        1        -        -        -        -       12        -
MEAN                     -  1497.00     6.00    30.00        -   580.00    57.42    41.33    95.00        -        -        -        -    59.92        -
STD DEV                  -      .00      .00      .00        -      .00    36.15    25.52      .00        -        -        -        -    42.79        -

COD       2/ 0/69        -  39480.0        -        -        -        -        -        -        -        -        -        -        -        -        -
# OBS                    -        1        -        -        -        -        -        -        -        -        -        -        -        -        -
MEAN                     - 39480.00        -        -        -        -        -        -        -        -        -        -        -        -        -
STD DEV                  -      .00        -        -        -        -        -        -        -        -        -        -        -        -        -

TS        8/26/74        -        -     458.     918.        -    2236.        -        -    1578.        -        -        -        -        -        -
# OBS                    -        -        1        1        -        1        -        -        1        -        -        -        -        -        -
MEAN                     -        -     458.     918.        -    2236.        -        -    1578.        -        -        -        -        -        -
STD DEV                  -        -       0.       0.        -       0.        -        -       0.        -        -        -        -        -        -
```

Reproduced from best available copy.

MILLFILL

MONITOR POINTS

PARAM	DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TDS	2/ 0/69	-	19144.	-	-	-	-	-	-	-	-	-	-	-	-	-
	6/29/70	-	-	-	-	-	-	431.	346.	-	-	-	-	-	431.	-
	3/ 9/71	-	-	-	-	-	-	492.	377.	-	-	-	-	-	461.	-
	8/ 7/71	-	-	-	-	-	-	437.	336.	-	-	-	-	-	409.	-
	6/13/72	-	-	-	-	-	-	438.	438.	-	-	-	-	-	330.	-
# OBS		-	1	-	-	-	-	4	4	-	-	-	-	-	4	-
MEAN		-	19144.	-	-	-	-	450.	374.	-	-	-	-	-	408.	-
STD DEV		-	0.	-	-	-	-	29.	46.	-	-	-	-	-	96.	-
NO3-N	2/ 0/69	-	1.700	-	-	-	-	-	-	-	-	-	-	-	-	-
# OBS		-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
MEAN		-	1.700	-	-	-	-	-	-	-	-	-	-	-	-	-
STD DEV		-	.000	-	-	-	-	-	-	-	-	-	-	-	-	-
PO4-P	2/ 0/69	-	6.000	-	-	-	-	-	-	-	-	-	-	-	-	-
	6/29/70	-	-	-	-	-	-	< .010	.100	-	-	-	-	-	.100	-
	3/ 9/71	-	-	-	-	-	-	< .010	< .010	-	-	-	-	-	< .010	-
	8/ 7/71	-	-	-	-	-	-	.100	< .010	-	-	-	-	-	< .010	-
	7/14/71	-	-	-	-	-	-	.100	.050	-	-	-	-	-	.100	-
	6/13/72	-	-	-	-	-	-	.060	.040	-	-	-	-	-	.020	-
# OBS		-	1	-	-	-	-	5	5	-	-	-	-	-	5	-
MEAN		-	6.000	-	-	-	-	.052	.038	-	-	-	-	-	.044	-
STD DEV		-	.000	-	-	-	-	.050	.041	-	-	-	-	-	.052	-
CU	2/ 0/69	-	< .050	-	-	-	-	-	-	-	-	-	-	-	-	-
# OBS		-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
MEAN		-	.000	-	-	-	-	-	-	-	-	-	-	-	-	-
STD DEV		-	.000	-	-	-	-	-	-	-	-	-	-	-	-	-
FE	2/ 0/69	-	5500.000	-	-	-	-	-	-	-	-	-	-	-	-	-
	3/17/69	-	-	-	-	-	-	.050	.200	-	-	-	-	-	.050	-
	4/21/69	-	-	-	-	-	-	.500	.400	-	-	-	-	-	.200	-
	6/25/69	-	-	-	-	-	-	.300	.600	-	-	-	-	-	.900	-
	8/14/69	-	-	-	-	-	-	.050	.200	-	-	-	-	-	.100	-
	10/13/69	-	-	-	-	-	-	.200	.700	-	-	-	-	-	.050	-
	10/27/69	-	-	-	-	-	-	.300	1.900	-	-	-	-	-	.400	-
	6/29/70	-	-	-	-	-	-	.200	1.400	-	-	-	-	-	.100	-
	7/16/70	-	-	-	-	-	-	.200	.400	-	-	-	-	-	.100	-
	3/ 9/71	-	-	-	-	-	-	.200	0.0	-	-	-	-	-	.200	-
	8/ 7/71	-	-	-	-	-	-	.300	.100	-	-	-	-	-	.200	-
	7/14/71	-	-	-	-	-	-	1.700	.100	-	-	-	-	-	3.400	-
	6/13/72	-	-	-	-	-	-	.400	.400	-	-	-	-	-	.200	-
	8/26/74	-	-	3.000	160.000	-	50.000	-	-	40.000	-	-	-	-	-	-
# OBS		-	1	1	1	-	1	12	12	1	-	-	-	-	12	-
MEAN		-	5500.000	3.000	160.000	-	50.000	.367	.533	40.000	-	-	-	-	.492	-
STD DEV		-	.000	.000	.000	-	.000	.439	.571	.000	-	-	-	-	.945	-
MN	2/ 0/69	-	1.660	-	-	-	-	-	-	-	-	-	-	-	-	-
	8/26/74	-	-	.220	18.500	-	.760	-	-	3.000	-	-	-	-	-	-
# OBS		-	1	1	1	-	1	-	-	1	-	-	-	-	-	-
MEAN		-	1.660	.220	18.500	-	.760	-	-	3.000	-	-	-	-	-	-
STD DEV		-	.000	.000	.000	-	.000	-	-	.000	-	-	-	-	-	-

```
                                                                HILLFILL
                                                                        MONITOR POINTS
PARAM    DATE         1         2        3        4        5        6        7        8        9       10       11       12       13       14       15

NA       2/ 0/69      .   900.000        .        .        .        .        .        .        .        .        .        .        .        .        .
# OBS                 .         1        .        .        .        .        .        .        .        .        .        .        .        .        .
MEAN                  .   900.000        .        .        .        .        .        .        .        .        .        .        .        .        .
STD DEV               .      .000        .        .        .        .        .        .        .        .        .        .        .        .        .

PB       2/ 0/69      .     1.300        .        .        .        .        .        .        .        .        .        .        .        .        .
         8/26/74      .         -     .020     .010        .     .010        .        .     .040        .        .        .        .        .        .
# OBS                 .         1        1        1        .        1        .        .        1        .        .        .        .        .        .
MEAN                  .     1.300     .020     .010        .     .010        .        .     .040        .        .        .        .        .        .
STD DEV               .      .000     .000     .000        .     .000        .        .     .000        .        .        .        .        .        .

ZN       2/ 0/69      .    40.000        .        .        .        .        .        .        .        .        .        .        .        .        .
# OBS                 .         1        .        .        .        .        .        .        .        .        .        .        .        .        .
MEAN                  .    40.000        .        .        .        .        .        .        .        .        .        .        .        .        .
STD DEV               .      .000        .        .        .        .        .        .        .        .        .        .        .        .        .

BOD 20   2/ 0/69      .    54610.        .        .        .        .        .        .        .        .        .        .        .        .        .
# OBS                 .         1        .        .        .        .        .        .        .        .        .        .        .        .        .
MEAN                  .    54610.        .        .        .        .        .        .        .        .        .        .        .        .        .
STD DEV               .        0.        .        .        .        .        .        .        .        .        .        .        .        .        .

CN       2/ 0/69      .      .024        .        .        .        .        .        .        .        .        .        .        .        .        .
# OBS                 .         1        .        .        .        .        .        .        .        .        .        .        .        .        .
MEAN                  .      .024        .        .        .        .        .        .        .        .        .        .        .        .        .
STD DEV               .      .000        .        .        .        .        .        .        .        .        .        .        .        .        .

HARD     2/ 0/69      .    7430.0        .        .        .        .        .        .        .        .        .        .        .        .        .
         8/26/74      .         -    400.0    780.0        .   1200.0        .        .   1200.0        .        .        .        .        .        .
# OBS                 .         1        1        1        .        1        .        .        1        .        .        .        .        .        .
MEAN                  .    7430.0    400.0    780.0        .   1200.0        .        .   1200.0        .        .        .        .        .        .
STD DEV               .        .0       .0       .0        .       .0        .        .       .0        .        .        .        .        .        .

HEXSOL   2/ 0/69      .      350.        .        .        .        .        .        .        .        .        .        .        .        .        .
# OBS                 .         1        .        .        .        .        .        .        .        .        .        .        .        .        .
MEAN                  .      350.        .        .        .        .        .        .        .        .        .        .        .        .        .
STD DEV               .        0.        .        .        .        .        .        .        .        .        .        .        .        .        .

AG       2/ 0/69      .    4  .01        .        .        .        .        .        .        .        .        .        .        .        .        .
# OBS                 .         1        .        .        .        .        .        .        .        .        .        .        .        .        .
MEAN                  .       .00        .        .        .        .        .        .        .        .        .        .        .        .        .
STD DEV               .       .00        .        .        .        .        .        .        .        .        .        .        .        .        .

AL       2/ 0/69      .     2.200        .        .        .        .        .        .        .        .        .        .        .        .        .
# OBS                 .         1        .        .        .        .        .        .        .        .        .        .        .        .        .
MEAN                  .     2.200        .        .        .        .        .        .        .        .        .        .        .        .        .
STD DEV               .      .000        .        .        .        .        .        .        .        .        .        .        .        .        .
```

```
                                                      HILLFILL
                                                              MONITOR POINTS
PARAM    DATE      1        2        3        4       5        6       7        8        9      10     11     12     13     14     15

AS       2/ 0/69   -      4.310      -        -       -        -       -        -        -      -      -      -      -      -      -
         8/26/74   -        -      .005     .150      -      .036      -        -      .009     -      -      -      -      -      -
# OBS              -          1       1        1      -         1      -        -         1     -      -      -      -      -      -
MEAN               -      4.310    .005     .150      -      .036      -        -      .009     -      -      -      -      -      -
STD DEV            -       .000    .000     .000      -      .000      -        -      .000     -      -      -      -      -      -

B        2/ 0/69   -      320.0      -        -       -        -       -        -        -      -      -      -      -      -      -
         8/26/74   -        -        .2       .4      -        .9      -        -        .3     -      -      -      -      -      -
# OBS              -          1       1        1      -         1      -        -         1     -      -      -      -      -      -
MEAN               -      320.0      .2       .4      -        .9      -        -        .3     -      -      -      -      -      -
STD DEV            -         .0      .0       .0      -        .0      -        -        .0     -      -      -      -      -      -

BA       2/ 0/69   -      8.500      -        -       -        -       -        -        -      -      -      -      -      -      -
         8/26/74   -        -      .200    5.000      -      .900      -        -     1.400     -      -      -      -      -      -
# OBS              -          1       1        1      -         1      -        -         1     -      -      -      -      -      -
MEAN               -      8.500    .200    5.000      -      .900      -        -     1.400     -      -      -      -      -      -
STD DEV            -       .000    .000     .000      -      .000      -        -      .000     -      -      -      -      -      -

CD       2/ 0/69   -    < .050       -        -       -        -       -        -        -      -      -      -      -      -      -
         8/26/74   -        -    < .050 <  .050       -    < .050      -        -    < .050     -      -      -      -      -      -
# OBS              -          1       1        1      -         1      -        -         1     -      -      -      -      -      -
MEAN               -       .000    .000     .000      -      .000      -        -      .000     -      -      -      -      -      -
STD DEV            -       .000    .000     .000      -      .000      -        -      .000     -      -      -      -      -      -

CR       2/ 0/69   -       .200      -        -       -        -       -        -        -      -      -      -      -      -      -
# OBS              -          1      -        -       -        -       -        -        -      -      -      -      -      -      -
MEAN               -       .200      -        -       -        -       -        -        -      -      -      -      -      -      -
STD DEV            -       .000      -        -       -        -       -        -        -      -      -      -      -      -      -

CR+6     2/ 0/69   -        .20      -        -       -        -       -        -        -      -      -      -      -      -      -
# OBS              -          1      -        -       -        -       -        -        -      -      -      -      -      -      -
MEAN               -        .20      -        -       -        -       -        -        -      -      -      -      -      -      -
STD DEV            -        .00      -        -       -        -       -        -        -      -      -      -      -      -      -

F        2/ 0/69   -       790.      -        -       -        -       -        -        -      -      -      -      -      -      -
# OBS              -          1      -        -       -        -       -        -        -      -      -      -      -      -      -
MEAN               -       790.      -        -       -        -       -        -        -      -      -      -      -      -      -
STD DEV            -         0.      -        -       -        -       -        -        -      -      -      -      -      -      -

MG       2/ 0/69   -     600.00      -        -       -        -       -        -        -      -      -      -      -      -      -
# OBS              -          1      -        -       -        -       -        -        -      -      -      -      -      -      -
MEAN               -     600.00      -        -       -        -       -        -        -      -      -      -      -      -      -
STD DEV            -        .00      -        -       -        -       -        -        -      -      -      -      -      -      -

SE       2/ 0/69   -      2.700      -        -       -        -       -        -        -      -      -      -      -      -      -
         8/26/74   -        -    < .050 <  .050       -    < .050      -        -    < .050     -      -      -      -      -      -
# OBS              -          1       1        1      -         1      -        -         1     -      -      -      -      -      -
MEAN               -     2.7000   .0000    .0000      -     .0000      -        -     .0000     -      -      -      -      -      -
STD DEV            -      .0000   .0000    .0000      -     .0000      -        -     .0000     -      -      -      -      -      -
```

```
                                                                   BALEFILL
                                                 MONITOR POINTS
PARAM    DATE       1        2        3        4        5        6        7

PH      3/29/74    6.7       -        -        -        -        -        -
        4/13/74    6.5       -        -        -        -        -        -
        4/28/74    -         -        -        -        -        -        -
        5/21/74    6.8       -        -        -        -        -        -
        5/27/74    6.4       -        -        -        -        -        -
        6/ 2/74    6.6       -        -        -        -        -        -
        6/16/74    6.4       -        -        -        -        -        -
        6/26/74    7.2       -        -        -        -        -        -
        7/ 2/74    7.1       -        -        -        -        -        -
        7/30/74    7.0       -        -        -        -        -        -
        8/ 6/74    7.1       -        -        -        -        -        -
        8/14/74    7.1       -        -        -        -        -        -
        9/ 3/74    6.3       -        -        -        -        -        -
        9/17/74    6.5       -        -        -        -        -        -
        9/25/74    6.8       -        -        -        -        -        -
       10/14/74    6.8       -        -        -        -        -        -
       10/21/74    6.4       -        -        -        -        -        -
       10/28/74    6.9       -        -        -        -        -        -
       11/ 2/76    7.1       -        -        -        -        -        -
        3/22/77    7.1       -        -        -        -        -        -
        6/29/77    6.2       -        -        -        -        -        -
        9/12/77    7.2       -        -        -        -        -        -
       12/19/77    7.0       -        -        -        -        -        -
        3/16/78    6.9       -        -        -        -        -        -
# OBS               23       -        -        -        -        -        -
MEAN               6.8       -        -        -        -        -        -
STD DEV             .3       -        -        -        -        -        -

ALK    11/ 2/76   39.0       -        -        -        -        -        -
        3/22/77   40.0       -        -        -        -        -        -
        6/29/77   50.0       -        -        -        -        -        -
        9/12/77 1410.0       -        -        -        -        -        -
       12/19/77 1280.0       -        -        -        -        -        -
        3/16/78 1380.0       -        -        -        -        -        -
# OBS                6       -        -        -        -        -        -
MEAN             699.8       -        -        -        -        -        -
STD DEV          720.8       -        -        -        -        -        -

SO4     3/29/74    -         -        -        -        -        -        -
        4/13/74    -         -        -        -        -        -        -
        4/28/74    -         -        -        -        -        -        -
        5/21/74 <     .1     -        -        -        -        -        -
        5/27/74       .7     -        -        -        -        -        -
        6/ 2/74      1.0     -        -        -        -        -        -
        6/16/74 <     .1     -        -        -        -        -        -
        6/26/74       .5     -        -        -        -        -        -
        7/ 2/74 <     .1     -        -        -        -        -        -
        7/30/74 <     .1     -        -        -        -        -        -
        8/ 6/74      1.1     -        -        -        -        -        -
        8/14/74       .8     -        -        -        -        -        -
        9/ 3/74      1.0     -        -        -        -        -        -
        9/17/74 <     .1     -        -        -        -        -        -
        9/25/74      1.0     -        -        -        -        -        -
       10/14/74 <     .1     -        -        -        -        -        -
       10/21/74       .5     -        -        -        -        -        -
       10/28/74       .7     -        -        -        -        -        -
```

```
# OBS                 15    .    .    .    .    .    .
MEAN                  .5    .    .    .    .    .    .
STD DEV               .4    .    .    .    .    .    .

SC      11/ 2/76  4280.0    .    .    .    .    .    .
         3/22/77  3670.0    .    .    .    .    .    .
         6/29/77  5830.0    .    .    .    .    .    .
         9/12/77  6400.0    .    .    .    .    .    .
        12/19/77  6540.0    .    .    .    .    .    .
         3/16/78  6470.0    .    .    .    .    .    .
# OBS                  6    .    .    .    .    .    .
MEAN              5531.7    .    .    .    .    .    .
STD DEV           1246.8    .    .    .    .    .    .

CL       3/29/74     .      .    .    .    .    .    .
         4/13/74     .      .    .    .    .    .    .
         4/28/74     .      .    .    .    .    .    .
         5/21/74   411.0    .    .    .    .    .    .
         5/27/74   367.0    .    .    .    .    .    .
         6/ 2/74   355.0    .    .    .    .    .    .
         6/16/74   411.0    .    .    .    .    .    .
         6/26/74   422.0    .    .    .    .    .    .
         7/ 2/74   444.0    .    .    .    .    .    .
         7/30/74   410.0    .    .    .    .    .    .
         8/ 6/74   350.0    .    .    .    .    .    .
         8/14/74   395.0    .    .    .    .    .    .
         9/ 3/74   447.0    .    .    .    .    .    .
         9/17/74   385.0    .    .    .    .    .    .
         9/25/74   405.0    .    .    .    .    .    .
        10/14/74   390.0    .    .    .    .    .    .
        10/21/74   350.0    .    .    .    .    .    .
        10/28/74   418.0    .    .    .    .    .    .
        11/ 2/76    49.0    .    .    .    .    .    .
         3/22/77    26.0    .    .    .    .    .    .
         6/29/77    39.0    .    .    .    .    .    .
         9/12/77    59.0    .    .    .    .    .    .
        12/19/77    69.0    .    .    .    .    .    .
         3/16/78   104.0    .    .    .    .    .    .
# OBS                 21    .    .    .    .    .    .
MEAN              300.29    .    .    .    .    .    .
STD DEV           159.97    .    .    .    .    .    .

TOC     11/ 2/76    98.0    .    .    .    .    .    .
         3/22/77   120.0    .    .    .    .    .    .
         6/29/77   238.0    .    .    .    .    .    .
         9/12/77   253.0    .    .    .    .    .    .
        12/19/77   354.0    .    .    .    .    .    .
         3/16/78   492.0    .    .    .    .    .    .
# OBS                  6    .    .    .    .    .    .
MEAN               259.2    .    .    .    .    .    .
STD DEV            147.7    .    .    .    .    .    .

COD     11/ 2/76   459.0    .    .    .    .    .    .
         3/22/77   419.0    .    .    .    .    .    .
         6/29/77   653.0    .    .    .    .    .    .
         9/12/77  1220.0    .    .    .    .    .    .
        12/19/77   748.0    .    .    .    .    .    .
         3/16/78   807.0    .    .    .    .    .    .
# OBS                  6    .    .    .    .    .    .
MEAN              717.67    .    .    .    .    .    .

STD DEV           290.36    .    .    .    .    .    .
```

```
                                                                     BALEFILL
                                                  MONITOR POINTS
PARAM    DATE          1        2         3          4         5          6         7

TDS      3/29/74    2640.       -         -          -         -          -         -
         4/13/74    1380.       -         -          -         -          -         -
         4/28/74      -         -         -          -         -          -         -
         5/21/74    1988.       -         -          -         -          -         -
         5/27/74    1884.       -         -          -         -          -         -
         6/ 2/74    1850.       -         -          -         -          -         -
         6/16/74    1912.       -         -          -         -          -         -
         6/26/74    2200.       -         -          -         -          -         -
         7/ 2/74    2051.       -         -          -         -          -         -
         7/30/74    1900.       -         -          -         -          -         -
         8/ 6/74    2862.       -         -          -         -          -         -
         8/14/74    1564.       -         -          -         -          -         -
         9/ 3/74    2015.       -         -          -         -          -         -
         9/17/74    1854.       -         -          -         -          -         -
         9/25/74    1960.       -         -          -         -          -         -
        10/14/74    1956.       -         -          -         -          -         -
        10/21/74    2008.       -         -          -         -          -         -
        10/28/74    1888.       -         -          -         -          -         -
        11/ 2/76    2000.       -         -          -         -          -         -
         3/22/77    1900.       -         -          -         -          -         -
         6/29/77    3100.       -         -          -         -          -         -
         9/12/77    3470.       -         -          -         -          -         -
        12/19/77    3760.       -         -          -         -          -         -
         3/16/78    3800.       -         -          -         -          -         -
# OBS                  23       -         -          -         -          -         -
MEAN                2241.       -         -          -         -          -         -
STD DEV              665.       -         -          -         -          -         -

NO3-N    3/29/74     .340       -         -          -         -          -         -
         4/13/74     .970       -         -          -         -          -         -
         4/28/74     -          -         -          -         -          -         -
         5/21/74     .370       -         -          -         -          -         -
         5/27/74     .260       -         -          -         -          -         -
         6/ 2/74     .280       -         -          -         -          -         -
         6/16/74     .290       -         -          -         -          -         -
         6/26/74     .380       -         -          -         -          -         -
         7/ 2/74     .350       -         -          -         -          -         -
         7/30/74     .500       -         -          -         -          -         -
         8/ 6/74     .350       -         -          -         -          -         -
         8/14/74     .280       -         -          -         -          -         -
         9/ 3/74     .300       -         -          -         -          -         -
         9/17/74     -          -         -          -         -          -         -
         9/25/74     -          -         -          -         -          -         -
        10/14/74     -          -         -          -         -          -         -
        10/21/74     -          -         -          -         -          -         -
        10/28/74     -          -         -          -         -          -         -
        11/ 2/76    6.500       -         -          -         -          -         -
         3/22/77    1.700       -         -          -         -          -         -
         6/29/77    2.300       -         -          -         -          -         -
         9/12/77    2.600       -         -          -         -          -         -
        12/19/77    6.100       -         -          -         -          -         -
         3/16/78    8.500       -         -          -         -          -         -
# OBS                  18       -         -          -         -          -         -
MEAN                1.798       -         -          -         -          -         -
STD DEV             2.551       -         -          -         -          -         -
```

```
NH3-N    3/29/74      -       -       -       -       -       -       -
         4/13/74      -       -       -       -       -       -       -
         4/28/74      -       -       -       -       -       -       -
         5/21/74   8.000      -       -       -       -       -       -
         5/27/74  13.000      -       -       -       -       -       -
         6/ 2/74  10.000      -       -       -       -       -       -
         6/16/74   9.000      -       -       -       -       -       -
         6/26/74  17.400      -       -       -       -       -       -
         7/ 2/74  24.400      -       -       -       -       -       -
         7/30/74  20.300      -       -       -       -       -       -
         8/ 6/74      -       -       -       -       -       -       -
         8/14/74  25.000      -       -       -       -       -       -
         9/ 3/74  26.200      -       -       -       -       -       -
         9/17/74      -       -       -       -       -       -       -
         9/25/74      -       -       -       -       -       -       -
        10/14/74      -       -       -       -       -       -       -
        10/21/74      -       -       -       -       -       -       -
        10/28/74      -       -       -       -       -       -       -
# OBS                 9       -       -       -       -       -       -
MEAN             17.033       -       -       -       -       -       -
STD DEV           7.284       -       -       -       -       -       -

PO4-P   11/ 2/76    .160      -       -       -       -       -       -
         3/22/77    .030      -       -       -       -       -       -
         6/29/77    .030      -       -       -       -       -       -
         9/12/77    .130      -       -       -       -       -       -
        12/19/77   1.300      -       -       -       -       -       -
         3/16/78    .125      -       -       -       -       -       -
# OBS                 6       -       -       -       -       -       -
MEAN               .296       -       -       -       -       -       -
STD DEV            .495       -       -       -       -       -       -

TKN     11/ 2/76   80.00      -       -       -       -       -       -
         3/22/77   79.00      -       -       -       -       -       -
         6/29/77  123.00      -       -       -       -       -       -
         9/12/77  260.00      -       -       -       -       -       -
        12/19/77  235.00      -       -       -       -       -       -
         3/16/78  154.00      -       -       -       -       -       -
# OBS                 6       -       -       -       -       -       -
MEAN             155.17       -       -       -       -       -       -
STD DEV           77.27       -       -       -       -       -       -

CU      11/ 2/76 <  .020      -       -       -       -       -       -
         3/22/77    .200      -       -       -       -       -       -
         6/29/77    .140      -       -       -       -       -       -
         9/12/77    .700      -       -       -       -       -       -
        12/19/77    .050      -       -       -       -       -       -
         3/16/78    .040      -       -       -       -       -       -
# OBS                 6       -       -       -       -       -       -
MEAN               .188       -       -       -       -       -       -
STD DEV            .261       -       -       -       -       -       -

MN      11/ 2/76    .040      -       -       -       -       -       -
         3/22/77    .250      -       -       -       -       -       -
         6/29/77    .100      -       -       -       -       -       -
         9/12/77    .300      -       -       -       -       -       -
        12/19/77 <  .040      -       -       -       -       -       -
         3/16/78    .250      -       -       -       -       -       -
# OBS                 6       -       -       -       -       -       -
MEAN               .157       -       -       -       -       -       -

STD DEV            .126       -       -       -       -       -       -
```

```
                                                   MONITOR POINTS              BALEFILL
PARAM     DATE          1         2         3         4         5         6         7

NA       11/ 2/76 575.000         -         -         -         -         -         -
          3/22/77 460.000         -         -         -         -         -         -
          6/29/771080.000         -         -         -         -         -         -
          9/12/772450.000         -         -         -         -         -         -
         12/19/771100.000         -         -         -         -         -         -
          3/16/78 812.000         -         -         -         -         -         -
# OBS                   6         -         -         -         -         -         -
MEAN             1079.500         -         -         -         -         -         -
STD DEV           719.520         -         -         -         -         -         -

PB       11/ 2/76 <  .160         -         -         -         -         -         -
          3/22/77 <  .160         -         -         -         -         -         -
          6/29/77    .020         -         -         -         -         -         -
          9/12/77    .450         -         -         -         -         -         -
         12/19/77 <  .200         -         -         -         -         -         -
          3/16/78 < 1.000         -         -         -         -         -         -
# OBS                   6         -         -         -         -         -         -
MEAN                 .078         -         -         -         -         -         -
STD DEV              .182         -         -         -         -         -         -

ZN       11/ 2/76    .010         -         -         -         -         -         -
          3/22/77    .150         -         -         -         -         -         -
          6/29/77    .060         -         -         -         -         -         -
          9/12/77    .100         -         -         -         -         -         -
         12/19/77    .360         -         -         -         -         -         -
          3/16/78    .280         -         -         -         -         -         -
# OBS                   6         -         -         -         -         -         -
MEAN                 .160         -         -         -         -         -         -
STD DEV              .135         -         -         -         -         -         -

ACID-0   11/ 2/76     11.         -         -         -         -         -         -
          3/22/77 <   10.         -         -         -         -         -         -
          6/29/77     44.         -         -         -         -         -         -
          9/12/77     38.         -         -         -         -         -         -
         12/19/77     73.         -         -         -         -         -         -
          3/16/78     46.         -         -         -         -         -         -
# OBS                   6         -         -         -         -         -         -
MEAN                  35.         -         -         -         -         -         -
STD DEV               26.         -         -         -         -         -         -

BOD 5     3/29/74     -           -         -         -         -         -         -
          4/13/74   167.0         -         -         -         -         -         -
          4/28/74     -           -         -         -         -         -         -
          5/21/74    25.0         -         -         -         -         -         -
          5/27/74   125.0         -         -         -         -         -         -
          6/ 2/74   155.0         -         -         -         -         -         -
          6/16/74   310.0         -         -         -         -         -         -
          6/26/74   505.0         -         -         -         -         -         -
          7/ 2/74   145.0         -         -         -         -         -         -
          7/30/74    50.0         -         -         -         -         -         -
          8/ 6/74   545.0         -         -         -         -         -         -
          8/14/74   140.0         -         -         -         -         -         -
          9/ 3/74   225.0         -         -         -         -         -         -
          9/17/74 <   1.0         -         -         -         -         -         -
          9/25/74    25.0         -         -         -         -         -         -
         10/14/74    85.0         -         -         -         -         -         -
```

```
          10/21/74    85.0   .    .    .    .    .    .
          10/28/74    80.0   .    .    .    .    .    .
          11/ 2/76    30.0   .    .    .    .    .    .
           3/22/77    20.0   .    .    .    .    .    .
           6/29/77    35.0   .    .    .    .    .    .
           9/12/77   235.0   .    .    .    .    .    .
          12/19/77   310.0   .    .    .    .    .    .
           3/16/78    45.0   .    .    .    .    .    .
# OBS                   22   .    .    .    .    .    .
MEAN                 151.9   .    .    .    .    .    .
STD DEV              151.1   .    .    .    .    .    .

BOD 20 11/ 2/76       480.   .    .    .    .    .    .
           3/22/77    140.   .    .    .    .    .    .
           6/29/77    100.   .    .    .    .    .    .
           9/12/77   1515.   .    .    .    .    .    .
          12/19/77    470.   .    .    .    .    .    .
           3/16/78    120.   .    .    .    .    .    .
# OBS                    6   .    .    .    .    .    .
MEAN                  471.   .    .    .    .    .    .
STD DEV               540.   .    .    .    .    .    .

IC        11/ 2/76    160.   .    .    .    .    .    .
           3/22/77    276.   .    .    .    .    .    .
           6/29/77    437.   .    .    .    .    .    .
           9/12/77    433.   .    .    .    .    .    .
          12/19/77    383.   .    .    .    .    .    .
           3/16/78    520.   .    .    .    .    .    .
# OBS                    6   .    .    .    .    .    .
MEAN                  368.   .    .    .    .    .    .
STD DEV               130.   .    .    .    .    .    .
```

```
                                                                BALEFILL
                                                MONITOR POINTS
PARAM     DATE          1        2        3        4        5        6        7

NO2-N   11/ 2/76       .010      -        -        -        -        -        -
         3/22/77       .003      -        -        -        -        -        -
         6/29/77       .019      -        -        -        -        -        -
         9/12/77       .059      -        -        -        -        -        -
        12/19/77       .220      -        -        -        -        -        -
         3/16/78       .012      -        -        -        -        -        -
# OBS                     6      -        -        -        -        -        -
MEAN                   .054      -        -        -        -        -        -
STD DEV                .084      -        -        -        -        -        -

ORG-N    3/29/74      -          -        -        -        -        -        -
         4/13/74      -          -        -        -        -        -        -
         4/28/74      -          -        -        -        -        -        -
         5/21/74      12.5       -        -        -        -        -        -
         5/27/74      11.3       -        -        -        -        -        -
         6/ 2/74      13.0       -        -        -        -        -        -
         6/16/74      20.0       -        -        -        -        -        -
         6/26/74      14.6       -        -        -        -        -        -
         7/ 2/74      16.2       -        -        -        -        -        -
         7/30/74      17.5       -        -        -        -        -        -
         8/ 6/74      -          -        -        -        -        -        -
         8/14/74      20.0       -        -        -        -        -        -
         9/ 3/74      16.5       -        -        -        -        -        -
         9/17/74      -          -        -        -        -        -        -
         9/25/74      -          -        -        -        -        -        -
        10/14/74      -          -        -        -        -        -        -
        10/21/74      -          -        -        -        -        -        -
        10/28/74      -          -        -        -        -        -        -
# OBS                     9      -        -        -        -        -        -
MEAN                   15.7      -        -        -        -        -        -
STD DEV                 3.1      -        -        -        -        -        -

CA      11/ 2/76     128.00      -        -        -        -        -        -
         3/22/77      75.00      -        -        -        -        -        -
         6/29/77      73.00      -        -        -        -        -        -
         9/12/77     170.00      -        -        -        -        -        -
        12/19/77      60.00      -        -        -        -        -        -
         3/16/78     230.00      -        -        -        -        -        -
# OBS                     6      -        -        -        -        -        -
MEAN                 122.67      -        -        -        -        -        -
STD DEV               67.02      -        -        -        -        -        -

CD      11/ 2/76       .006      -        -        -        -        -        -
         3/22/77       .025      -        -        -        -        -        -
         6/29/77 <     .006      -        -        -        -        -        -
         9/12/77 <     .250      -        -        -        -        -        -
        12/19/77 <     .250      -        -        -        -        -        -
         3/16/78 <     .500      -        -        -        -        -        -
# OBS                     6      -        -        -        -        -        -
MEAN                   .005      -        -        -        -        -        -
STD DEV                .010      -        -        -        -        -        -

CR      11/ 2/76 <     .300      -        -        -        -        -        -
         3/22/77 <     .300      -        -        -        -        -        -
         6/29/77 <     .300      -        -        -        -        -        -
         9/12/77 <     .300      -        -        -        -        -        -
```

```
             12/19/77 < 1.000    .    .    .    .    .    .
              3/16/78 < 1.000    .    .    .    .    .    .
 # OBS                      6    .    .    .    .    .    .
 MEAN                    .000    .    .    .    .    .    .
 STD DEV                 .000    .    .    .    .    .    .

 MG         11/ 2/76   200.00    .    .    .    .    .    .
             3/22/77    88.00    .    .    .    .    .    .
             6/29/77   140.00    .    .    .    .    .    .
             9/12/77   107.00    .    .    .    .    .    .
            12/19/77   111.00    .    .    .    .    .    .
             3/16/78    78.00    .    .    .    .    .    .
 # OBS                      6    .    .    .    .    .    .
 MEAN                  120.67    .    .    .    .    .    .
 STD DEV                44.35    .    .    .    .    .    .

 NI         11/ 2/76      .10    .    .    .    .    .    .
             3/22/77      .20    .    .    .    .    .    .
             6/29/77      .13    .    .    .    .    .    .
             9/12/77      .06    .    .    .    .    .    .
            12/19/77      .12    .    .    .    .    .    .
             3/16/78      .01    .    .    .    .    .    .
 # OBS                      6    .    .    .    .    .    .
 MEAN                     .10    .    .    .    .    .    .
 STD DEV                  .06    .    .    .    .    .    .

 S           3/29/74    .        .    .    .    .    .    .
             4/13/74    .        .    .    .    .    .    .
             4/28/74    .        .    .    .    .    .    .
             5/21/74 <  .100     .    .    .    .    .    .
             5/27/74 <  .100     .    .    .    .    .    .
             6/ 2/74 <  .100     .    .    .    .    .    .
             6/16/74 <  .100     .    .    .    .    .    .
             6/26/74 <  .100     .    .    .    .    .    .
             7/ 2/74 <  .100     .    .    .    .    .    .
             7/30/74 <  .100     .    .    .    .    .    .
             8/ 6/74 <  .100     .    .    .    .    .    .
             8/14/74 <  .100     .    .    .    .    .    .
             9/ 3/74 <  .100     .    .    .    .    .    .
             9/17/74 <  .100     .    .    .    .    .    .
             9/25/74    .100     .    .    .    .    .    .
            10/14/74    .100     .    .    .    .    .    .
            10/21/74    .100     .    .    .    .    .    .
            10/28/74    .100     .    .    .    .    .    .
 # OBS                    15     .    .    .    .    .    .
 MEAN                   .027     .    .    .    .    .    .
 STD DEV                .046     .    .    .    .    .    .
```

```
                                                                 MILLFILL
                                            MONITOR POINTS
PARAM     DATE        1         2         3         4         5         6         7         8

PH      10/17/74     6.9        -        6.5        -         -         -         -         -
         4/11/75     7.3       7.9       6.5       6.2       5.5        -         -         -
         9/ 9/75     7.7       7.3       6.7       6.9       6.2        -         -         -
        12/22/75     7.2       7.1       6.6       6.2       6.0        -         -         -
         4/19/76     7.7       7.3       6.8       7.7       7.5        -         -         -
         7/ 9/76     6.8       7.9       6.8       7.3       5.7        -         -         -
         9/30/76     7.6       7.1       6.7       7.2       6.5        -         -         -
         1/21/77     7.6       7.4       7.5       7.4       6.9        -         -         -
         4/13/77      -        7.9        -         -         -         -         -         -
         8/ 3/77     6.3       7.4       7.0       6.6       6.3        -         -         -
        11/15/77     7.7       6.9       6.7       5.8       5.4        -         -         -
         2/27/78     7.6       7.4       7.6       6.2       6.1        -         -         -
         6/ 2/78     7.4       6.9       6.6       6.7       6.5        -         -         -
         9/14/78     7.4       6.7       6.6        -        6.5        -         -         -
# OBS                 13        13        13        11        12        -         -         -
MEAN                 7.3       7.3       6.8       6.7       6.3        -         -         -
STD DEV               .4        .4        .4        .6        .6        -         -         -

ALK     10/17/74    46.0        -       22.0        -         -         -         -         -
         4/11/75    66.0      35.0      28.0      29.0      14.0        -         -         -
         9/ 9/75   110.0     124.0      43.0     128.0      58.0        -         -         -
        12/22/75   127.0     174.0      36.0      47.0      21.0        -         -         -
         4/19/76   121.0     140.0      60.0      58.0       8.0        -         -         -
         7/ 9/76    69.0     183.0      69.0      88.0      10.0        -         -         -
         9/30/76     1.6       1.6        .7       1.4       1.6        -         -         -
         1/21/77   150.0     215.0      50.0      40.0      10.0        -         -         -
         4/13/77      -      450.0        -         -         -         -         -         -
         8/ 3/77    30.0     500.0      50.0      50.0      30.0        -         -         -
        11/15/77   160.0     480.0       6.0       9.0       3.0        -         -         -
         2/27/78   118.7     790.0     118.7      18.1      11.5        -         -         -
         6/ 2/78   207.0     518.0      97.0     170.0     213.0        -         -         -
         9/14/78   201.5     299.1      73.3        -       91.6        -         -         -
# OBS                 13        13        13        11        12        -         -         -
MEAN               108.3     300.7      50.3      58.0      39.3        -         -         -
STD DEV             63.4     230.1      33.9      51.9      60.7        -         -         -

SO4     10/17/74    23.0        -       25.0        -         -         -         -         -
         4/11/75      -       34.0        -       32.0      32.0        -         -         -
         4/19/76    26.0      23.0      20.0      20.0      21.0        -         -         -
         6/ 2/78     2.5       4.3      14.3      11.8       3.2        -         -         -
# OBS                  3         3         3         3         3        -         -         -
MEAN                17.2      20.4      19.8      21.3      18.7        -         -         -
STD DEV             12.8      15.0       5.4      10.2      14.5        -         -         -

SC      10/17/74    70.0        -       32.0        -         -         -         -         -
         4/11/75   370.0     250.0     127.0     130.0     135.0        -         -         -
         9/ 9/75   280.0     270.0      98.0     167.0     108.0        -         -         -
        12/22/75    52.0      74.0      22.0     125.0     180.0        -         -         -
         4/19/76   238.0     220.0      92.0     116.0      33.2        -         -         -
         7/ 9/76   180.0     330.0     180.0     280.0     210.0        -         -         -
         9/30/76   315.0     232.0     180.0     176.0     168.0        -         -         -
         1/21/77   165.0     188.0      74.0      70.0      62.0        -         -         -
         4/13/77      -      503.0        -         -         -         -         -         -
         8/ 3/77    96.0     916.0     194.0     110.0      96.0        -         -         -
        11/15/77   400.0     175.0     175.0      42.5      42.5        -         -         -
         2/27/78   160.0     400.0     160.0      70.0      49.0        -         -         -
```

Reproduced from
best available copy.

```
          6/ 2/78    350.0    725.0    152.0    250.0    449.0     -       -       -
          9/14/78    400.0    450.0    150.0      -      170.0     -       -       -
# OBS                   13       13       13       11       12     -       -       -
MEAN                 228.6    402.3    125.8    141.5    141.9     -       -       -
STD DEV              117.0    271.0     57.4     75.0    113.6     -       -       -

CL       10/17/74     13.0      -        4.0      -        -       -       -       -
          4/11/75     21.0      8.0      4.0      4.0      4.0     -       -       -
          9/ 9/75     17.0      4.0      4.0     11.0      9.0     -       -       -
         12/22/75     10.0     15.0      4.0      5.0      2.0     -       -       -
          4/19/76     10.0      2.0      2.0      5.0 <    1.0     -       -       -
          7/ 9/76      4.0      4.0      4.0      2.0      2.0     -       -       -
          9/30/76     15.0      -        2.5      2.5     10.0     -       -       -
          1/21/77     15.0     10.0      5.0      6.0      2.5     -       -       -
          4/13/77      -        5.0      -        -        -       -       -       -
          8/ 3/77      5.0      7.5 <    5.0 <    5.0      5.0     -       -       -
         11/15/77     21.0     12.5      5.0      5.0      5.0     -       -       -
          2/27/78 <    5.0      7.5 <    5.0 <    5.0 <    5.0     -       -       -
          6/ 2/78     16.9      2.1      1.1      1.6      1.6     -       -       -
          9/14/78     14.3      4.2      1.1      -        2.1     -       -       -
# OBS                   13       12       13       11       12     -       -       -
MEAN                 12.48     6.82     2.82     3.83     3.60     -       -       -
STD DEV               6.44     4.08     1.80     3.16     3.20     -       -       -

COD      10/17/74     12.0      -   <   10.0      -        -       -       -       -
          4/11/75      -   <   10.0      -   <   10.0 <   10.0     -       -       -
         12/22/75      -   <   10.0      -       12.0     66.0     -       -       -
          4/19/76 <   10.0 <   10.0     40.0 <   10.0 <   10.0     -       -       -
          6/ 2/78 <    1.0      7.9 <    1.0     15.9     15.9     -       -       -
# OBS                    3        4        3        4        4     -       -       -
MEAN                  4.00     1.97    13.33     6.98    20.47     -       -       -
STD DEV               6.93     3.95    23.09     8.21    31.26     -       -       -

TS       10/17/74     154.      -       110.      -        -       -       -       -
          4/11/75     176.     198.     138.     408.     924.     -       -       -
          9/ 9/75     256.    1918.     184.    1710.   11734.     -       -       -
         12/22/75     210.     272.      70.     404.     186.     -       -       -
          4/19/76     232.     490.     158.     252.     412.     -       -       -
          9/30/76     256.     226.     124.     248.     398.     -       -       -
          1/21/77     360.     314.     360.    1408.    1216.     -       -       -
          4/13/77      -       502.      -        -        -       -       -       -
          8/ 3/77     342.     248.     132.     310.     342.     -       -       -
         11/15/77     264.     622.      90.     230.     304.     -       -       -
          2/27/78     142.     576.     142.     124.     132.     -       -       -
          6/ 2/78     272.     492.     180.    1048.    1034.     -       -       -
          9/14/78     136.     336.     136.      -       280.     -       -       -
# OBS                   12       12       12       10       11     -       -       -
MEAN                  233.     516.     152.     614.    1542.     -       -       -
STD DEV                73.     464.      73.     563.    3400.     -       -       -
```

```
                                                                      MILLFILL
                                                     MONITOR POINTS
PARAM    DATE          1         2         3         4         5         6         7         8

NO3-N  10/17/74      .700      -         .700      -         -         -         -         -
        4/11/75      -        1.100      -        1.000      .800      -         -         -
        4/19/76      .900     1.000      .400      .800      .400      -         -         -
        6/ 2/78      .700      .200      .200      .200      .200      -         -         -
# OBS                   3         3         3         3         3      -         -         -
MEAN                 .767      .767      .433      .667      .467      -         -         -
STD DEV              .115      .493      .252      .416      .306      -         -         -

NH3-N  10/17/74 <    .100      -    <    .100      -         -         -         -         -
        4/11/75      -         .800      -    <    .100 <    .100      -         -         -
        4/19/76 <    .100      .100 <    .100 <    .100 <    .100      -         -         -
        6/ 2/78      .800      .800      .800      .300      .600      -         -         -
# OBS                   3         3         3         3         3      -         -         -
MEAN                 .267      .567      .267      .100      .200      -         -         -
STD DEV              .462      .404      .462      .173      .346      -         -         -

PO4-P  10/17/74     3.900      -         .300      -         -         -         -         -
        4/11/75      -         .550      -         .300      .200      -         -         -
        4/19/76      .100      .100      .200      .200      .300      -         -         -
        6/ 2/78      .030 <    .010 <    .010      .040 <    .100      -         -         -
# OBS                   3         3         3         3         3      -         -         -
MEAN                1.343      .217      .167      .180      .167      -         -         -
STD DEV             2.214      .293      .153      .131      .153      -         -         -

TKN    10/17/74       .10      -          .30      -         -         -         -         -
        4/11/75      -          .40      -          .10       .40      -         -         -
        4/19/76      4.60      1.60       .20      3.20      2.40      -         -         -
        6/ 2/78      1.10      9.00     54.90      7.30     15.90      -         -         -
# OBS                   3         3         3         3         3      -         -         -
MEAN                 1.93      3.67     18.47      3.53      6.23      -         -         -
STD DEV              2.36      4.66     31.55      3.61      8.43      -         -         -

FE     10/17/74 <    .100      -    <    .100      -         -         -         -         -
        4/11/75 <    .100      .500 <    .100      .500      .400      -         -         -
        9/ 9/75      .100     3.000 <    .100      .900     2.500      -         -         -
       12/22/75      .200      .200      .100      .500     1.500      -         -         -
        4/19/76 <    .100     1.300 <    .100      .200     2.400      -         -         -
        7/ 9/76     1.500      .200     1.500      .400      .700      -         -         -
        9/30/76 <    .100      -    <    .100      .500     5.000      -         -         -
        1/21/77 <    .100 <    .100 <    .100      .700      .600      -         -         -
        4/13/77      -         .700      -         -         -         -         -         -
        8/ 3/77     1.050      .700 <    .100      .650     1.050      -         -         -
       11/15/77 <    .200 <    .200 <    .200 <    .200      .700      -         -         -
        2/27/78 <    .200 <    .200 <    .200      .240      .450      -         -         -
        6/ 2/78 <    .200    27.300 <    .200     9.500    19.700      -         -         -
        9/14/78 <    .200 <    .200 <    .200      -         .450      -         -         -
# OBS                  13        12        13        11        12      -         -         -
MEAN                 .219     2.825      .123     1.281     2.954      -         -         -
STD DEV              .041     7.755      .415     2.737     5.441      -         -         -

BOD 5  10/17/74 <      .1      -           .6      -         -         -         -         -
        4/11/75        .2        .5        .7       1.0       1.5      -         -         -
        9/ 9/75      -         -         -         -         -         -         -         -
       12/22/75      -          3.0      -          4.2       8.5      -         -         -
        4/19/76       1.3 <      .1 <      .1       2.4       2.2      -         -         -
        8/ 3/77        .3        .7       2.6       1.0        .3      -         -         -
```

Reproduced from
best available copy.

```
           6/ 2/78      1.5      5.5 <   1.0       .5 <   1.0      -        -        -
# OBS                     5        5       5        5       5      -        -        -
MEAN                     .7      1.5      .8      1.8     2.5      -        -        -
STD DEV                  .7      1.6     1.1      1.5     3.5      -        -        -

COLOR   10/17/74        30.      -       39.      -       -        -        -        -
         4/11/75 <       1.       1. <    1.      90.     70.      -        -        -
         9/ 9/75         2.     190. <    1.     195.   2800.      -        -        -
        12/22/75 <       1.      10. <    1.      60.    120.      -        -        -
         4/19/76         4.      70. <    1. <    1.    110.      -        -        -
         7/ 9/76         1.       1.      1.       3.      5.      -        -        -
         9/30/76 <      10.     130. <   10.      20.    220.      -        -        -
         1/21/77         1.       1. <    1.     140.    100.      -        -        -
         4/13/77       -         12.    -        -       -        -        -        -
         8/ 3/77        45.       8. <    1.      25.     45.      -        -        -
        11/15/77        12.      10. <   10.      30.     50.      -        -        -
         2/27/78 <       5. <     5. <    5.      10.     30.      -        -        -
         6/ 2/78 <       5.      15.     10.      15.     85.      -        -        -
         9/14/78        10.       1.     10.      -       35.      -        -        -
# OBS                    13       13      13       11      12      -        -        -
MEAN                     8.      35.      5.      53.    306.      -        -        -
STD DEV                 14.      60.     11.      63.    787.      -        -        -
```

```
                                                                      MILLFILL
                                                   MONITOR POINTS
PARAM    DATE          1         2         3         4         5      6         7         8

HARD    10/17/74     122.0         -      66.0         -         -      -         -         -
         4/11/75     160.0      92.0      64.0      18.0       8.0      -         -         -
         9/ 9/75     170.0     151.0      68.0     110.0      43.0      -         -         -
        12/22/75     169.0     196.0     118.0      28.0      39.0      -         -         -
         4/19/76     178.0     180.0      94.0      35.0      27.0      -         -         -
         7/ 9/76      80.0     209.0      80.0     105.0      31.0      -         -         -
         9/30/76     200.0     155.0      75.0     130.0      50.0      -         -         -
         1/21/77     175.0     220.0      60.0      50.0      25.0      -         -         -
         4/13/77         -     450.0         -         -         -      -         -         -
         8/ 3/77      30.0     310.0      70.0      50.0      30.0      -         -         -
        11/15/77     200.0     300.0      50.0      40.0      40.0      -         -         -
         2/27/78      80.0     520.0      80.0      30.0      20.0      -         -         -
         6/ 2/78     150.0     310.0      60.0     100.0      10.0      -         -         -
         9/14/78     150.0     190.0      40.0         -      30.0      -         -         -
# OBS                   13        13        13        11        12      -         -         -
MEAN                 143.4     252.5      71.2      63.3      29.4      -         -         -
STD DEV               51.4     122.6      19.7      39.8      12.7      -         -         -

NO2-N   10/17/74 <    .010         -  <   .010         -         -      -         -         -
         4/11/75         -      .020         -      .030      .020      -         -         -
         4/19/76 <    .010 <    .010  <   .010 <    .010 <    .010      -         -         -
         6/ 2/78    13.500     7.300     1.000     9.300     7.300      -         -         -
# OBS                    3         3         3         3         3      -         -         -
MEAN                 4.500     2.440      .333     3.110     2.440      -         -         -
STD DEV              7.794     4.209      .577     5.361     4.209      -         -         -

TURB    10/17/74      4.00         -      4.00         -         -      -         -         -
         4/11/75 <    1.00      1.00 <    1.00     19.00     12.00      -         -         -
         9/ 9/75      1.00      6.40 <    1.00     68.00    960.00      -         -         -
        12/22/75 <    1.00 <    1.00 <    1.00     18.00     18.00      -         -         -
         4/19/76 <    1.00      2.00 <    1.00 <    1.00     19.00      -         -         -
         7/ 9/76 <    1.00 <    1.00 <    1.00 <    1.00 <    1.00      -         -         -
         9/30/76 <   10.00    165.00 <   10.00     10.00    120.00      -         -         -
         1/21/77       .10     38.00       .10    120.00     90.00      -         -         -
         4/13/77         -       .54         -         -         -      -         -         -
         8/ 3/77     22.00      4.00 <    1.00     14.00     22.00      -         -         -
        11/15/77 <     .50       .90 <     .50     26.00     48.00      -         -         -
         2/27/78       .11     12.00       .11     23.00     32.00      -         -         -
         6/ 2/78      1.80    130.00      2.80    340.00    200.00      -         -         -
         9/14/78      1.00     10.00      3.00         -     18.00      -         -         -
# OBS                   13        13        13        11        12      -         -         -
MEAN                  2.31     28.45       .77     58.00    123.25      -         -         -
STD DEV               6.03     54.28      1.45     99.90    251.39      -         -         -
```

STRIP MINE LANDFILL
MONITOR POINTS

PARAM	DATE	1	2	3	4	5	6	7	8	9	10
PH	4/ 0/73	6.9	-	-	-	-	-	-	-	-	-
	4/ 4/73	6.9	6.6	7.4	-	-	-	-	-	-	-
	6/ 0/73	7.0	-	-	-	-	-	-	-	-	-
	6/22/73	7.0	6.3	7.4	-	-	-	-	-	-	-
	1/ 0/74	6.9	-	-	-	-	-	-	-	-	-
	1/ 8/74	6.9	6.2	7.6	-	-	-	-	-	-	-
	3/ 0/75	7.5	-	-	-	-	-	-	-	-	-
	3/19/75	7.5	6.7	7.3	-	-	-	-	-	-	-
	8/ 0/75	8.1	-	-	-	-	-	-	-	-	-
	8/ 1/75	8.1	8.2	7.4	-	-	-	-	-	-	-
	3/ 0/76	7.1	-	-	-	-	-	-	-	-	-
	3/ 1/76	7.1	7.4	6.7	-	-	-	-	-	-	-
	4/ 0/77	6.6	-	-	-	-	-	-	-	-	-
	4/11/77	6.6	-	7.3	-	-	-	-	-	-	-
	8/11/77	7.6	7.5	6.9	-	-	-	-	-	-	-
	6/ 0/78	7.2	7.2	-	-	-	-	-	-	-	-
# OBS		16	8	8	-	-	-	-	-	-	-
MEAN		7.2	7.0	7.3	-	-	-	-	-	-	-
STD DEV		.5	.7	.3	-	-	-	-	-	-	-
ALK	4/ 0/73	180.0	-	-	-	-	-	-	-	-	-
	4/ 4/73	180.0	14.0	70.0	-	-	-	-	-	-	-
	6/ 0/73	220.0	-	-	-	-	-	-	-	-	-
	6/22/73	220.0	40.0	102.0	-	-	-	-	-	-	-
	1/ 0/74	164.0	-	-	-	-	-	-	-	-	-
	1/ 8/74	164.0	12.0	110.0	-	-	-	-	-	-	-
	3/ 0/75	56.0	-	-	-	-	-	-	-	-	-
	3/19/75	56.0	16.0	54.0	-	-	-	-	-	-	-
	8/ 0/75	146.0	-	-	-	-	-	-	-	-	-
	8/ 1/75	146.0	186.0	60.0	-	-	-	-	-	-	-
	3/ 0/76	3.6	-	-	-	-	-	-	-	-	-
	3/ 1/76	36.0	76.0	28.0	-	-	-	-	-	-	-
	4/11/77	54.0	80.0	32.0	-	-	-	-	-	-	-
	8/11/77	102.0	126.0	38.0	-	-	-	-	-	-	-
	6/ 0/78	58.0	58.0	-	-	-	-	-	-	-	-
# OBS		15	9	8	-	-	-	-	-	-	-
MEAN		119.0	67.6	61.8	-	-	-	-	-	-	-
STD DEV		70.6	58.2	30.9	-	-	-	-	-	-	-
SO4	4/ 0/73	165.0	-	-	-	-	-	-	-	-	-
	4/ 4/73	165.0	55.0	70.0	-	-	-	-	-	-	-
	6/ 0/73	145.0	-	-	-	-	-	-	-	-	-
	6/22/73	145.0	23.0	70.0	-	-	-	-	-	-	-
	1/ 0/74	195.0	-	-	-	-	-	-	-	-	-
	1/ 8/74	195.0	47.0	115.0	-	-	-	-	-	-	-
	3/ 0/75	62.7	-	-	-	-	-	-	-	-	-
	3/19/75	62.7	38.3	66.0	-	-	-	-	-	-	-
	8/ 0/75	173.0	-	-	-	-	-	-	-	-	-
	8/ 1/75	173.0	160.0	25.0	-	-	-	-	-	-	-
	3/ 1/76	120.0	105.0	30.0	-	-	-	-	-	-	-
	4/11/77	120.0	120.0	35.0	-	-	-	-	-	-	-
	8/11/77	56.0	56.0	32.0	-	-	-	-	-	-	-
	6/ 0/78	94.6	82.3	-	-	-	-	-	-	-	-
# OBS		14	9	8	-	-	-	-	-	-	-
MEAN		133.7	76.3	55.4	-	-	-	-	-	-	-
STD DEV		48.7	44.4	30.8	-	-	-	-	-	-	-

```
SC        4/ 0/73    550.0       -         -      .    .    .    .    .    .    .
          4/ 4/73    550.0     140.0     260.0    .    .    .    .    .    .    .
          6/ 0/73    580.0       -         -      .    .    .    .    .    .    .
          6/22/73    580.0     120.0     290.0    .    .    .    .    .    .    .
          1/ 0/74    500.0       -         -      .    .    .    .    .    .    .
          1/ 8/74    500.0     140.0     350.0    .    .    .    .    .    .    .
          3/ 0/75    350.0       -         -      .    .    .    .    .    .    .
          3/19/75    305.0     100.0     290.0    .    .    .    .    .    .    .
          8/ 0/75    510.0       -         -      .    .    .    .    .    .    .
          8/ 1/75    510.0     535.0     170.0    .    .    .    .    .    .    .
          3/ 0/76    278.0       -         -      .    .    .    .    .    .    .
          3/ 1/76    278.0     290.0     108.0    .    .    .    .    .    .    .
          4/ 0/77    230.0       -         -      .    .    .    .    .    .    .
          4/11/77    230.0     270.0     100.0    .    .    .    .    .    .    .
          8/11/77    340.0     375.0     120.0    .    .    .    .    .    .    .
          6/ 0/78    900.0    1000.0       -      .    .    .    .    .    .    .
# OBS                   16         9         8    .    .    .    .    .    .    .
MEAN                 449.4     330.0     211.0    .    .    .    .    .    .    .
STD DEV              176.6     288.8      97.9    .    .    .    .    .    .    .

CL        4/ 0/73      5.0       -         -      .    .    .    .    .    .    .
          4/ 4/73      5.0 <     5.0 <     5.0    .    .    .    .    .    .    .
          6/ 0/73     11.0       -         -      .    .    .    .    .    .    .
          6/22/73     11.0       1.0 <     5.0    .    .    .    .    .    .    .
          1/ 0/74      7.0       -         -      .    .    .    .    .    .    .
          1/ 8/74      7.0 <     5.0 <     5.0    .    .    .    .    .    .    .
          3/ 0/75      4.5       -         -      .    .    .    .    .    .    .
          3/19/75      4.5 <     5.0       6.0    .    .    .    .    .    .    .
          8/ 0/75      4.0       -         -      .    .    .    .    .    .    .
          8/ 1/75      4.0       6.0 <     5.0    .    .    .    .    .    .    .
          3/ 0/76      1.0       -         -      .    .    .    .    .    .    .
          3/ 1/76      1.0       3.0 <     5.0    .    .    .    .    .    .    .
          4/11/77      2.0       3.0 <     5.0    .    .    .    .    .    .    .
          6/ 0/78 <     .1 <      .1       -      .    .    .    .    .    .    .
# OBS                   14         8         7    .    .    .    .    .    .    .
MEAN                  4.79      1.63       .86    .    .    .    .    .    .    .
STD DEV               3.37      2.20      2.27    .    .    .    .    .    .    .

COD       4/ 0/73     16.0       -         -      .    .    .    .    .    .    .
          4/ 4/73     16.0      12.0      12.0    .    .    .    .    .    .    .
          6/ 0/73     88.0       -         -      .    .    .    .    .    .    .
          6/22/73     88.0      32.0      24.0    .    .    .    .    .    .    .
          1/ 0/74     16.0       -         -      .    .    .    .    .    .    .
          1/ 8/74     16.0      38.0      36.0    .    .    .    .    .    .    .
          3/ 0/75     65.0       -         -      .    .    .    .    .    .    .
          3/19/75     65.0      30.0      74.0    .    .    .    .    .    .    .
          8/ 0/75       -        -         -      .    .    .    .    .    .    .
          8/ 1/75     34.0      32.0      32.0    .    .    .    .    .    .    .
          3/ 0/76     31.0       -         -      .    .    .    .    .    .    .
          3/ 1/76     31.0      35.0      27.0    .    .    .    .    .    .    .
          4/11/77     10.0      12.0      10.0    .    .    .    .    .    .    .
          8/11/77     20.0      20.0      16.0    .    .    .    .    .    .    .
          6/ 0/78 <    5.0 <     5.0       -      .    .    .    .    .    .    .
# OBS                   14         9         8    .    .    .    .    .    .    .
MEAN                 35.43     23.44     28.88    .    .    .    .    .    .    .
STD DEV              29.05     13.03     20.46    .    .    .    .    .    .    .

TS        4/ 0/73     464.       -         -      .    .    .    .    .    .    .
          4/ 4/73     464.      178.      206.    .    .    .    .    .    .    .
```

```
           6/ 0/73   534.     -       -      -      -      -      -      -      -      -
           6/22/73   534.    152.    736.    -      -      -      -      -      -      -
           1/ 0/74   492.     -       -      -      -      -      -      -      -      -
           1/ 8/74   492.   1366.    318.    -      -      -      -      -      -      -
           3/ 0/75   238.     -       -      -      -      -      -      -      -      -
           3/19/75   238.     92.    234.    -      -      -      -      -      -      -
           8/ 0/75   428.     -       -      -      -      -      -      -      -      -
           8/ 1/75   428.    474.    242.    -      -      -      -      -      -      -
           3/ 0/76   208.     -       -      -      -      -      -      -      -      -
           3/ 1/76   208.    250.     96.    -      -      -      -      -      -      -
           4/11/77   242.    252.    102.    -      -      -      -      -      -      -
           8/11/77   346.    376.    142.    -      -      -      -      -      -      -
           6/ 0/78   208.    220.     -      -      -      -      -      -      -      -
# OBS                  15       9       8    -      -      -      -      -      -      -
MEAN                 368.    373.    260.    -      -      -      -      -      -      -
STD DEV              131.    390.    207.    -      -      -      -      -      -      -
```

```
                                                  STRIP MINE LANDFILL
                                                     MONITOR POINTS
PARAM    DATE            1         2         3     4     5     6     7     8     9    10

NO3-N    6/22/73      .420      .210      .700     -     -     -     -     -     -     -
         1/ 8/74      .700       0.0      .790     -     -     -     -     -     -     -
         4/11/77      .600      .650      .240     -     -     -     -     -     -     -
         8/11/77      .320      .320      .250     -     -     -     -     -     -     -
         6/ 0/78  <   .100 <    .100         -     -     -     -     -     -     -     -
# OBS                    5         5         4     -     -     -     -     -     -     -
MEAN                  .408      .236      .495     -     -     -     -     -     -     -
STD DEV               .272      .269      .291     -     -     -     -     -     -     -

NH3-N    4/ 0/73      .560         -         -     -     -     -     -     -     -     -
         4/ 4/73      .560      .340      .360     -     -     -     -     -     -     -
         6/ 0/73     2.500         -         -     -     -     -     -     -     -     -
         6/22/73     2.500      .820     1.500     -     -     -     -     -     -     -
         1/ 0/74      .100         -         -     -     -     -     -     -     -     -
         1/ 8/74      .100     4.000      .240     -     -     -     -     -     -     -
         3/ 0/75         -         -         -     -     -     -     -     -     -     -
         8/ 0/75         -         -         -     -     -     -     -     -     -     -
         3/ 0/76         -         -         -     -     -     -     -     -     -     -
         4/11/77      .410      .460      .440     -     -     -     -     -     -     -
         8/11/77      .024      .028      .024     -     -     -     -     -     -     -
         6/ 0/78  <   .500 <    .500         -     -     -     -     -     -     -     -
# OBS                    9         6         5     -     -     -     -     -     -     -
MEAN                  .750      .941      .513     -     -     -     -     -     -     -
STD DEV              1.015     1.529      .574     -     -     -     -     -     -     -

FE       4/ 0/73      .107         -         -     -     -     -     -     -     -     -
         4/ 4/73      .107      .077      .057     -     -     -     -     -     -     -
         6/ 0/73     2.230         -         -     -     -     -     -     -     -     -
         6/22/73     2.230      .380    14.250     -     -     -     -     -     -     -
         1/ 0/74     4.500         -         -     -     -     -     -     -     -     -
         1/ 8/74     4.500    32.500     1.000     -     -     -     -     -     -     -
         3/ 0/75      .230         -         -     -     -     -     -     -     -     -
         3/19/75      .230      .320      .510     -     -     -     -     -     -     -
         8/ 0/75      .180         -         -     -     -     -     -     -     -     -
         8/ 1/75      .180      .240      .370     -     -     -     -     -     -     -
         3/ 0/76      .270         -         -     -     -     -     -     -     -     -
         3/ 1/76      .270      .520      .720     -     -     -     -     -     -     -
         4/11/77      .110      .120      .420     -     -     -     -     -     -     -
         8/11/77      .470      .320      .770     -     -     -     -     -     -     -
         6/ 0/78      .100      .100         -     -     -     -     -     -     -     -
# OBS                   15         9         8     -     -     -     -     -     -     -
MEAN                 1.048     3.842     2.262     -     -     -     -     -     -     -
STD DEV              1.571    10.748     4.852     -     -     -     -     -     -     -

MN       4/ 0/73         -         -         -     -     -     -     -     -     -     -
         6/ 0/73     2.000         -         -     -     -     -     -     -     -     -
         6/22/73     2.000 <    .005      .800     -     -     -     -     -     -     -
         1/ 0/74     1.200         -         -     -     -     -     -     -     -     -
         1/ 8/74     1.200     1.500 <    .005     -     -     -     -     -     -     -
         4/11/77  <   .005 <    .005 <    .005     -     -     -     -     -     -     -
         8/11/77         -      .050 <    .005     -     -     -     -     -     -     -
         6/ 0/78  <   .005 <    .005         -     -     -     -     -     -     -     -
# OBS                    6         5         4     -     -     -     -     -     -     -
MEAN                 1.067      .510      .200     -     -     -     -     -     -     -
STD DEV               .900      .666      .400     -     -     -     -     -     -     -
```

```
ROD 5    4/ 0/73     2.0       -         -      -      -      -      -      -      -      -
         4/ 4/73     2.0        .6      4.6     -      -      -      -      -      -      -
         6/ 0/73     2.0       -         -      -      -      -      -      -      -      -
         6/22/73     2.0       3.6      2.8     -      -      -      -      -      -      -
         1/ 0/74     1.6       -         -      -      -      -      -      -      -      -
         1/ 8/74     1.6       2.0      2.0     -      -      -      -      -      -      -
         3/ 0/75 <   2.0       -         -      -      -      -      -      -      -      -
         3/19/75 <   2.0 <     2.0 <    2.0     -      -      -      -      -      -      -
         8/ 0/75 <   2.0       -         -      -      -      -      -      -      -      -
         8/ 1/75 <   2.0 <     2.0 <    2.0     -      -      -      -      -      -      -
         3/ 0/76     1.0       -         -      -      -      -      -      -      -      -
         3/ 1/76     1.0       1.0      1.0     -      -      -      -      -      -      -
         4/11/77     1.0       1.0      1.0     -      -      -      -      -      -      -
         8/11/77     2.0       1.0      2.0     -      -      -      -      -      -      -
         6/ 0/78 <   2.0 <     2.0       -      -      -      -      -      -      -      -
# OBS                 15         9        8     -      -      -      -      -      -      -
MEAN                 1.1       1.0      1.7     -      -      -      -      -      -      -
STD DEV               .9       1.2      1.5     -      -      -      -      -      -      -

NO2-N    6/22/73    .044      .011     .022     -      -      -      -      -      -      -
         1/ 8/74    .015      .250     .003     -      -      -      -      -      -      -
         4/11/77    .010      .016     .014     -      -      -      -      -      -      -
         8/11/77    .023      .023     .024     -      -      -      -      -      -      -
         6/ 0/78 <  .010 <    .010      -       -      -      -      -      -      -      -
# OBS                  5         5        4     -      -      -      -      -      -      -
MEAN                .018      .060     .016     -      -      -      -      -      -      -
STD DEV             .017      .107     .010     -      -      -      -      -      -      -

ALB-N    6/22/73   1.200      .085     .720     -      -      -      -      -      -      -
         1/ 8/74    .124      .240     .148     -      -      -      -      -      -      -
         4/11/77    .110      .120     .165     -      -      -      -      -      -      -
         8/11/77    .068      .044     .044     -      -      -      -      -      -      -
         6/ 0/78 <  .010 <    .010      -       -      -      -      -      -      -      -
# OBS                  5         5        4     -      -      -      -      -      -      -
MEAN                .300      .098     .269     -      -      -      -      -      -      -
STD DEV             .505      .091     .305     -      -      -      -      -      -      -
```

STRIP MINE LANDFILL
MONITOR POINTS

PARAM	DATE	1	2	3	4	5	6	7	8	9	10
OPO4-P	6/22/73	.020	.020	.050	-	-	-	-	-	-	-
	1/ 8/74	.170	.470	.075	-	-	-	-	-	-	-
	4/11/77	.080	.100	.080	-	-	-	-	-	-	-
	8/11/77	.040	.040	.010	-	-	-	-	-	-	-
	6/ 0/78	< .010	< .010	-	-	-	-	-	-	-	-
# OBS		5	5	4	-	-	-	-	-	-	-
MEAN		.062	.126	.054	-	-	-	-	-	-	-
STD DEV		.067	.196	.032	-	-	-	-	-	-	-
PHENOL	8/11/77	< .020	< .020	< .020	-	-	-	-	-	-	-
	6/ 0/78	< .020	< .020	-	-	-	-	-	-	-	-
# OBS		2	2	1	-	-	-	-	-	-	-
MEAN		.000	.000	.000	-	-	-	-	-	-	-
STD DEV		.000	.000	.000	-	-	-	-	-	-	-
SET S	6/22/73	.20	.20	.60	-	-	-	-	-	-	-
	1/ 8/74	.10	1.50	.05	-	-	-	-	-	-	-
	4/11/77	< .10	< .10	< .10	-	-	-	-	-	-	-
	8/11/77	< .10	< .10	.30	-	-	-	-	-	-	-
	6/ 0/78	< .10	< .10	-	-	-	-	-	-	-	-
# OBS		5	5	4	-	-	-	-	-	-	-
MEAN		.06	.34	.24	-	-	-	-	-	-	-
STD DEV		.09	.65	.27	-	-	-	-	-	-	-
SS	6/22/73	30.00	98.00	222.00	-	-	-	-	-	-	-
	1/ 8/74	40.00	950.00	2.00	-	-	-	-	-	-	-
	4/11/77	2.00	6.00	4.00	-	-	-	-	-	-	-
	8/11/77	4.00	4.00	12.00	-	-	-	-	-	-	-
	6/ 0/78	7.00	10.00	-	-	-	-	-	-	-	-
# OBS		5	5	4	-	-	-	-	-	-	-
MEAN		16.60	213.60	60.00	-	-	-	-	-	-	-
STD DEV		17.26	413.56	108.09	-	-	-	-	-	-	-
AL	6/22/73	< .100	< .100	< .100	-	-	-	-	-	-	-
	1/ 8/74	4.800	.700	.024	-	-	-	-	-	-	-
	4/11/77	< .100	.030	< .100	-	-	-	-	-	-	-
	8/11/77	< .100	< .100	< .100	-	-	-	-	-	-	-
	6/ 0/78	.200	.200	-	-	-	-	-	-	-	-
# OBS		5	5	4	-	-	-	-	-	-	-
MEAN		1.000	.186	.006	-	-	-	-	-	-	-
STD DEV		2.126	.299	.012	-	-	-	-	-	-	-
F	6/22/73	.20	.10	.10	-	-	-	-	-	-	-
	1/ 8/74	< .10	< .10	< .10	-	-	-	-	-	-	-
	4/11/77	.10	.10	.10	-	-	-	-	-	-	-
	8/11/77	< .10	< .10	< .10	-	-	-	-	-	-	-
	6/ 0/78	< .10	< .10	-	-	-	-	-	-	-	-
# OBS		5	5	4	-	-	-	-	-	-	-
MEAN		.06	.04	.05	-	-	-	-	-	-	-
STD DEV		.09	.05	.06	-	-	-	-	-	-	-

PERMITTED SANITARY LANDFILL
MONITOR POINTS

PARAM	DATE	1	2	3	4	5	6	7	8	9	10
TEMP	1/11/78	8.0	8.0	8.0	8.0	8.0	8.0	-	-	-	-
	2/16/78	10.0	10.0	10.0	10.0	10.0	10.0	-	-	-	-
	3/10/78	9.0	9.0	12.0	10.0	9.0	10.0	2.0	-	-	-
	4/ 5/78	9.0	9.0	13.0	9.0	9.0	10.0	3.0	3.0	-	-
	5/10/78	10.0	10.0	14.0	11.0	11.0	11.0	10.0	11.0	-	-
	6/ 8/78	12.0	12.0	14.0	11.0	12.0	12.0	16.0	16.0	-	-
	7/12/78	11.0	12.0	14.0	11.0	11.0	12.0	12.0	13.0	-	-
	8/ 9/78	14.0	12.0	11.0	13.0	13.0	13.0	17.0	18.0	-	-
	9/13/78	-	11.0	14.0	12.0	11.0	11.0	12.0	12.0	-	-
	10/12/78	-	12.0	15.0	11.0	12.0	12.0	14.0	-	-	-
	11/14/78	-	12.0	14.0	11.0	12.0	12.0	14.0	14.0	-	-
	12/ 5/78	10.0	10.0	13.0	11.0	10.0	10.0	3.0	2.0	-	-
# OBS		9	12	12	12	12	12	10	8	-	-
MEAN		10.3	10.6	12.7	10.7	10.7	10.9	10.3	11.1	-	-
STD DEV		1.8	1.4	2.1	1.3	1.5	1.4	5.6	5.8	-	-
PH	1/17/75	7.3	7.3	8.5	-	-	-	8.2	7.9	7.8	8.2
	4/12/75	7.0	6.7	7.7	-	-	-	7.7	7.6	7.3	7.5
	7/19/75	7.2	6.7	7.5	-	-	-	-	-	-	-
	8/14/75	7.2	6.8	7.6	-	-	-	-	-	-	-
	9/21/75	7.2	6.9	7.7	-	-	-	-	-	-	-
	1/11/78	6.8	6.8	8.2	7.8	7.8	8.8	6.5	7.2	-	-
	2/16/78	-	-	-	-	-	-	-	-	-	-
	3/10/78	6.6	6.4	7.2	8.2	6.4	7.5	7.2	-	-	-
	4/ 5/78	6.4	-	-	6.6	-	-	6.7	6.8	-	-
	5/10/78	7.5	7.0	7.9	7.4	7.8	8.1	7.9	7.9	-	-
	6/ 8/78	6.8	6.6	7.2	6.9	7.0	7.2	7.3	7.4	-	-
	7/12/78	6.9	7.3	7.5	7.6	7.5	7.8	7.1	6.9	-	-
	8/ 9/78	7.8	7.3	7.4	7.1	7.5	7.3	7.2	7.2	-	-
	9/13/78	-	7.5	7.8	7.3	7.6	7.8	7.0	7.1	-	-
	10/12/78	-	7.4	7.4	7.8	7.9	7.5	7.8	-	-	-
	11/14/78	-	7.5	7.4	7.4	7.8	7.6	7.8	7.7	-	-
	12/ 5/78	7.8	7.4	7.4	7.2	7.3	7.6	8.2	8.2	-	-
# OBS		13	15	15	11	10	10	13	11	2	2
MEAN		7.1	7.0	7.6	7.4	7.5	7.7	7.4	7.4	7.5	7.8
STD DEV		.4	.4	.4	.5	.5	.5	.5	.5	.4	.5
SO4	1/17/75	-	-	-	-	-	-	-	-	-	-
	4/12/75	120.0	27.0	17.0	-	-	-	17.0	19.0	23.0	42.0
	7/19/75	94.0	28.0	21.0	-	-	-	-	-	-	-
	8/14/75	105.0	30.0	22.0	-	-	-	-	-	-	-
	9/21/75	85.0	30.0	25.0	-	-	-	-	-	-	-
	1/11/78	-	-	-	-	-	-	22.0	20.0	-	-
	2/16/78	48.0	26.0	23.0	20.0	13.0	10.0	23.0	22.0	-	-
	3/10/78	-	-	-	-	-	-	25.0	-	-	-
	4/ 5/78	37.0	26.0	27.0	19.0	6.0	11.0	16.0	16.0	-	-
	5/10/78	-	-	-	-	-	-	22.5	21.5	-	-
	6/ 8/78	45.0	29.0	25.0	20.0	7.0	20.0	17.0	15.0	-	-
	7/12/78	-	-	-	-	-	-	23.0	21.0	-	-
	8/ 9/78	36.0	26.0	9.5	14.0	5.0	23.0	21.0	18.0	-	-
	9/13/78	-	-	-	-	-	-	19.0	25.0	-	-
	10/12/78	-	-	-	9.0	-	27.5 <	2.0	-	-	-
	11/14/78	-	-	-	-	-	-	-	-	-	-
	12/ 5/78	48.1	21.4 <	2.0	17.4	8.5	23.4	28.9	28.9	-	-
# OBS		9	9	9	6	5	6	12	10	1	1
MEAN		68.7	27.0	18.8	16.6	7.9	19.1	19.5	20.6	23.0	42.0
STD DEV		32.3	2.7	8.8	4.5	3.1	7.1	7.2	4.1	.0	.0

```
SC       1/17/75    950.0   1150.0   1440.0       -        -        -      365.0    295.0    380.0    485.0
         4/12/75    780.0   1120.0   1500.0       -        -        -      310.0    265.0    465.0    510.0
         7/19/75    835.0   1175.0   1530.0       -        -        -        -        -        -        -
         8/14/75    925.0   1090.0   1560.0       -        -        -        -        -        -        -
         9/21/75    970.0   1100.0   1500.0       -        -        -        -        -        -        -
         1/11/78    900.0   1200.0    490.0    420.0    680.0    240.0    235.0    250.0       -        -
         2/16/78   1400.0    640.0   1400.0    660.0    880.0    375.0    220.0    200.0       -        -
         3/10/78   1200.0    680.0   1200.0    480.0    680.0    460.0    260.0       -        -        -
         4/ 5/78   1200.0    620.0    760.0    490.0    720.0    470.0    180.0    220.0       -        -
         5/10/78    900.0    900.0    760.0    400.0    720.0    460.0    280.0    260.0       -        -
         6/ 8/78      -        -        -        -        -        -        -        -        -        -
         7/12/78   1200.0    880.0    820.0    360.0    680.0    450.0    330.0    400.0       -        -
         8/ 9/78    880.0    860.0    980.0    350.0    560.0    400.0    340.0    330.0       -        -
         9/13/78      -      980.0   1200.0    390.0    580.0    460.0    420.0    490.0       -        -
        10/12/78      -        -        -        -        -        -        -        -        -        -
        11/14/78      -        -        -        -        -        -        -        -        -        -
        12/ 5/78    960.0   1400.0   1600.0    400.0    600.0    480.0    220.0    220.0       -        -
# OBS                  13       14       14        9        9        9       11       10        2        2
MEAN               1007.7    985.4   1195.7    438.9    677.8    421.7    287.3    293.0    422.5    497.5
STD DEV             182.5    232.6    367.9     95.6     96.1     76.3     72.7     91.1     60.1     17.7

CL       1/17/75     56.0     15.0    540.0       -        -        -       36.0     33.0     14.0     38.0
         4/12/75     55.0     15.0    260.0       -        -        -       16.0     17.0     25.0     20.0
         7/19/75    100.0     10.0    610.0       -        -        -        -        -        -        -
         8/14/75     94.0     18.0    370.0       -        -        -        -        -        -        -
         9/21/75    100.0     11.0    460.0       -        -        -        -        -        -        -
         1/11/78     86.0      5.0    188.0      1.0     79.0     24.0      8.0      8.0       -        -
         2/16/78     86.0      8.0    164.0     26.0    138.0     30.0     10.0      8.0       -        -
         3/10/78     91.0      5.0     96.0      1.0     62.0     27.0     19.0       -        -        -
         4/ 5/78      1.2 <    2.0     78.5      1.2     60.7     22.7      7.2      6.7       -        -
         5/10/78     65.0     15.0     83.5      1.0     87.0     37.5     12.5     13.0       -        -
         6/ 8/78    105.0     25.0     96.9      4.0     72.9     24.9     15.9     11.9       -        -
         7/12/78      2.9 <    2.0    129.6 <    2.0     59.5     26.5     18.9     28.5       -        -
         8/ 9/78     80.0 <    1.0    174.0      1.0     59.0     24.0     22.0     35.0       -        -
         9/13/78      -        1.5     22.7      4.0     55.9     26.2     24.7     44.3       -        -
        10/12/78      -    <   1.0      9.8      2.5     77.9     19.9     22.7       -        -        -
        11/14/78      -    <   1.0     25.5      2.5     92.9     20.5     37.0     30.5       -        -
        12/ 5/78     67.9 <    1.0     26.8      2.4     47.8     26.8     32.5     26.8       -        -
# OBS                  14       17       17       12       12       12       14       12        2        2
MEAN                70.71     7.56   196.20     3.88    74.38    25.83    20.17    21.89    19.50    29.00
STD DEV             33.20     7.87   188.49     7.08    24.18     4.64     9.74    12.65     7.78    12.73

TOC      8/14/75     22.0     10.0      9.5       -        -        -        -        -        -        -
         9/21/75      -        4.3     10.0       -        -        -        -        -        -        -
# OBS                   1        2        2       -        -        -        -        -        -        -
MEAN                 22.0      7.1      9.6       -        -        -        -        -        -        -
STD DEV                .0      4.0       .5       -        -        -        -        -        -        -

COD      1/17/75 <    1.0 <    1.0     42.0       -        -        -       16.0      3.6      5.2      6.4
         4/12/75      8.4      2.8     31.0       -        -        -    <  1.0 <    1.0      1.2      1.2
         7/19/75       .8       .4      5.1       -        -        -        -        -        -        -
         8/14/75     16.0     16.0     39.0       -        -        -        -        -        -        -
         9/21/75     16.0     16.0     45.0       -        -        -        -        -        -        -
         1/11/78     42.4 <    2.0 <    2.0 <    2.0 <    2.0 <    2.0     12.7 <    2.0       -        -
         2/16/78     18.8     14.9     14.9     14.9     21.6     26.7      3.9      2.0       -        -
         3/10/78     28.8     21.1     17.3     17.3     86.4    465.0    196.0       -        -        -
         4/ 5/78     12.1     12.1     22.2 <    2.0      6.1      6.1      2.0     14.1       -        -
         5/10/78     31.7     31.7     27.7     31.7     31.7     51.5     15.8     15.8       -        -
```

```
          6/ 8/78    30.7     7.7    26.9    11.5    80.6    19.2   154.0    30.7      -       -
          7/12/78    45.3   482.0    19.5   103.0    10.3    10.3     2.1    26.8      -       -
          8/ 9/78    37.4    20.8    29.1    62.4     6.2    10.4    10.4    14.5      -       -
          9/13/78     -      26.0    24.4   167.0    10.9    49.7    12.8    26.4      -       -
         10/12/78     -      15.8    13.8    99.0     2.0     5.9     7.9     -        -       -
         11/14/78     -      10.0    19.0    30.0     7.0    11.0 <   2.0 <   2.0      -       -
         12/ 5/78    28.7    20.8    36.6    28.7    18.8    30.7    12.9    16.8      -       -
# OBS
                       14      17      17      12      12      12      14      12       2       2
MEAN                22.65   41.06   24.33   47.13   23.47   57.21   31.89   12.56    3.20    3.80
STD DEV             14.55  114.00   12.39   51.28   29.44  129.51   61.45   11.37    2.83    3.68
```

```
                                                   PERMITTED SANITARY LANDFILL
                                              MONITOR POINTS
PARAM    DATE         1        2        3        4        5        6        7        8        9       10

TDS      8/14/75    681.     791.     946.       -        -        -        -        -        -        -
         9/21/75     -       944.    1459.       -        -        -        -        -        -        -
# OBS                 1        2        2        -        -        -        -        -        -        -
MEAN                681.     868.    1193.       -        -        -        -        -        -        -
STD DEV               0.     108.     349.       -        -        -        -        -        -        -

NO3-N    8/14/75    .500    2.000 <   .100       -        -        -        -        -        -        -
         9/21/75     -    <  .100     .100       -        -        -        -        -        -        -
         1/11/78     -        -        -         -        -        -        -        -        -        -
         2/16/78   1.000    2.600     .220     .300     .200    1.600       -        -        -        -
         3/10/78    .200    2.000     .640     .100     .100     .760       -        -        -        -
         4/ 5/78    .480    1.900     .760     .310     .210     .360       -        -        -        -
         5/10/78   1.100    3.300     .460     .180     .390     .420       -        -        -        -
         6/ 8/78    .540    2.900     .540     .290     .340     .880       -        -        -        -
         7/12/78    .400    1.900     .340     .230     .160     .400       -        -        -        -
         8/ 9/78    .680    2.600     .570     .210     .190     .640       -        -        -        -
         9/13/78     -      2.140     .470     .250     .180     .470       -        -        -        -
        10/12/78     -      1.100     .110     .150 <   .050     .400       -        -        -        -
        11/14/78     -       .920     .140     .230     .100     .200       -        -        -        -
        12/ 5/78    .930    1.510     .360     .520     .440     .740       -        -        -        -
# OBS                 9       13       13       11       11       11        -        -        -        -
MEAN                .648    1.913     .362     .252     .210     .625       -        -        -        -
STD DEV             .303     .884     .235     .110     .132     .383       -        -        -        -

NH3-N    8/14/75    .050     .030     .270       -        -        -        -        -        -        -
         9/21/75     -       .040     .340       -        -        -        -        -        -        -
# OBS                 1        2        2        -        -        -        -        -        -        -
MEAN                .050     .035     .305       -        -        -        -        -        -        -
STD DEV             .000     .007     .049       -        -        -        -        -        -        -

PO4-P    8/14/75    .050     .050     .060       -        -        -        -        -        -        -
         9/21/75     -       .170     .050       -        -        -        -        -        -        -
# OBS                 1        2        2        -        -        -        -        -        -        -
MEAN                .050     .110     .055       -        -        -        -        -        -        -
STD DEV             .000     .085     .007       -        -        -        -        -        -        -

TKN      8/14/75     .90      .34      .48       -        -        -        -        -        -        -
         9/21/75     -        .45     1.90       -        -        -        -        -        -        -
# OBS                 1        2        2        -        -        -        -        -        -        -
MEAN                 .90      .39     1.19       -        -        -        -        -        -        -
STD DEV              .00      .08     1.00       -        -        -        -        -        -        -

CU       1/17/75    .020     .030     .510       -        -        -     <  .010 <   .010 <   .010 <   .010
         4/12/75    .020     .230     .190       -        -        -     <  .010 <   .010 <   .010     .080
         7/19/75     -        -        -         -        -        -        -        -        -        -
         8/14/75    .010     .200     .040       -        -        -        -        -        -        -
         9/21/75 <  .010     .050     .020       -        -        -        -        -        -        -
         1/11/78     -        -        -         -        -        -        -        -        -        -
         2/16/78 <  .100 <   .100 <   .100 <   .100 <   .100 <   .100       -        -        -        -
         3/10/78     -        -        -         -        -        -        -        -        -        -
         4/ 5/78 <  .100 <   .100 <   .100 <   .100 <   .100 <   .100       -        -        -        -
         5/10/78     -        -        -         -        -        -        -        -        -        -
         6/ 8/78 <  .100 <   .100 <   .100 <   .100 <   .100 <   .100       -        -        -        -
         7/12/78     -        -        -         -        -        -        -        -        -        -
         8/ 9/78    .100 <   .100     .100 <   .100 <   .100     .100       -        -        -        -
         9/13/78     -        -        -         -        -        -        -        -        -        -
```

```
            10/12/78      -  <   .100 <   .100 <   .100 <   .100 <   .100       -        -        -        -
            11/14/78      -        -        -        -        -        -        -        -        -        -
            12/ 5/78 <   .100 <   .100 <   .100 <   .100 <   .100 <   .100       -        -        -        -
# OBS                       9       10       10        6        6        6        2        2        2        2
MEAN                     .017     .051     .086     .000     .000     .017     .000     .000     .000     .040
STD DEV                  .032     .088     .161     .000     .000     .041     .000     .000     .000     .057

FE          1/17/75     8.100    4.700   17.000       -        -        -      .100     .040     .020     .210
            4/12/75     4.000     .440   34.000       -        -        -      .150     .180     .300     .260
            7/19/75     1.500     .380     .210       -        -        -        -        -        -        -
            8/14/75     1.800     .220 <   .010       -        -        -        -        -        -        -
            9/21/75     1.600     .190    6.900       -        -        -        -        -        -        -
            1/11/78    79.000   44.000   30.000    2.900   13.200   16.700     .210     .180       -        -
            2/16/78    14.800   24.100    5.400    6.900     .800   23.500 <   .300 <   .300       -        -
            3/10/78    12.800    7.500   25.800    2.000    3.200   15.900       -        -        -        -
            4/ 5/78    19.000   28.000   15.000    4.000    2.800   19.000     .500     .400       -        -
            5/10/78    23.400   11.200    3.200    4.400    1.500    4.300 <   .300 <   .300       -        -
            6/ 8/78    12.700    8.060    4.750    1.170    1.020    2.310     .120     .370       -        -
            7/12/78    23.100   15.900   16.100    4.240    4.640    9.840     .120     .320       -        -
            8/ 9/78    32.400   21.700   24.550    1.870    3.980   13.200     .050     .430       -        -
            9/13/78       -     11.510    7.550    2.990    1.910    5.580    1.030    1.730       -        -
           10/12/78       -      8.520    1.900     .230     .190    9.430     .180       -        -        -
           11/14/78       -      2.100    1.950    2.920     .260    8.860     .140     .070       -        -
           12/ 5/78    57.000   30.000   12.100    7.600    9.490   14.800     .130     .300       -        -
# OBS                      14       17       17       12       12       12       13       12        2        2
MEAN                   20.800   12.854   12.436    3.435    3.582   11.952     .210     .335     .160     .235
STD DEV                22.462   12.734   11.603    2.172    3.971    6.348     .276     .466     .198     .035
```

```
                                                              PERMITTED SANITARY LANDFILL
                                                      MONITOR POINTS
PARAM      DATE         1         2         3         4         5         6         7         8         9        10

MN        1/17/75         -         -         -         -         -         -         -         -         -         -
          4/12/75         -         -         -         -         -         -         -         -         -         -
          7/19/75      .090      .020      .110         -         -         -         -         -         -         -
          8/14/75      .100      .030      .100         -         -         -         -         -         -         -
          9/21/75      .070      .020      .150         -         -         -         -         -         -         -
          1/11/78      .580      .680     1.030      .500      .230      .230      .030      .020         -         -
          2/16/78      .276      .350      .172      .458      .094      .368      .016      .034         -         -
          3/10/78      .174      .086      .600      .574      .130      .222         -         -         -         -
          4/ 5/78      .580      .730      .420     1.500      .110      .260      .068      .068         -         -
          5/10/78      .399      .138      .273     2.310      .135      .113      .014      .014         -         -
          6/ 8/78      .263      .210      .615     1.016      .153      .100      .025      .070         -         -
          7/12/78      .303      .160      .228     3.400      .169      .177      .031      .046         -         -
          8/ 9/78      .265      .086      .202      .530      .054      .079      .030      .018         -         -
          9/13/78         -      .172      .057      .550      .161      .189      .102      .131         -         -
         10/12/78         -      .115      .160      .325      .115      .175      .050         -         -         -
         11/14/78         -      .045      .187     1.470      .099      .176      .093 <    .005         -         -
         12/ 5/78      .549      .351      .589     2.960      .184      .213      .012      .021         -         -
# OBS                    12        15        15        12        12        12        11        10         -         -
MEAN                   .304      .213      .326     1.299      .136      .192      .043      .043         -         -
STD DEV                .187      .225      .271     1.058      .047      .078      .032      .041         -         -

NA        1/17/75    15.000     3.500   280.000         -         -         -     8.700     8.700     2.500     4.600
          4/12/75    17.000     5.200   207.000         -         -         -     8.300     7.200     1.800     5.000
          7/19/75         -         -         -         -         -         -         -         -         -         -
          8/14/75    17.000     4.300   210.000         -         -         -         -         -         -         -
          9/21/75    18.000     5.500   180.000         -         -         -         -         -         -         -
# OBS                     4         4         4         -         -         -         2         2         2         2
MEAN                 16.750     4.625   219.250         -         -         -     8.500     7.950     2.150     4.800
STD DEV               1.258      .907    42.688         -         -         -      .283     1.061      .495      .283

PB        1/17/75         -         -         -         -         -         -         -         -         -         -
          4/12/75         -         -         -         -         -         -         -         -         -         -
          7/19/75 <    .030 <    .030 <    .030         -         -         -         -         -         -         -
          8/14/75 <    .030      .090 <    .030         -         -         -         -         -         -         -
          9/21/75 <    .030 <    .030 <    .030         -         -         -         -         -         -         -
          1/11/78      .006      .012      .038      .006      .021 <    .005 <    .005 <    .005         -         -
          2/16/78 <    .005 <    .005 <    .005 <    .005 <    .005 <    .005 <    .005 <    .005         -         -
          3/10/78 <    .005 <    .005      .017 <    .005      .006 <    .005         -         -         -         -
          4/ 5/78      .014      .077      .018      .020      .016      .017 <    .005 <    .005         -         -
          5/10/78      .009      .011      .070      .006      .038 <    .005 <    .005 <    .005         -         -
          6/ 8/78      .013      .011      .037      .005      .017 <    .005 <    .005 <    .005         -         -
          7/12/78      .042      .023      .070      .059      .033      .028 <    .005 <    .005         -         -
          8/ 9/78      .248      .063      .142 <    .005      .078      .023 <    .005 <    .005         -         -
          9/13/78         -      .023      .064      .031      .027      .016 <    .005 <    .005         -         -
         10/12/78         - <    .005 <    .005 <    .005 <    .005 <    .005 <    .005         -         -         -
         11/14/78         -      .008      .026      .011 <    .005      .018 <    .005 <    .005         -         -
         12/ 5/78      .143      .045      .175      .041      .171      .082 <    .005 <    .005         -         -
# OBS                    12        15        15        12        12        12        11        10         -         -
MEAN                   .040      .027      .044      .015      .034      .015      .000      .000         -         -
STD DEV                .077      .034      .053      .019      .048      .024      .000      .000         -         -

ZN        1/17/75      .030      .040      .350         -         -         -      .010      .007      .030      .330
          4/12/75      .050      .070      .120         -         -         -      .010      .010      .040      .330
          7/19/75         -         -         -         -         -         -         -         -         -         -
          8/14/75      .010      .050      .020         -         -         -         -         -         -         -
          9/21/75      .010      .050      .110         -         -         -         -         -         -         -
          1/11/78      -         -         -         -         -         -         -         -         -         -
          2/16/78 <   .500  <   .500  <   .500  <   .500  <   .500  <   .500       -         -         -         -
          3/10/78      -         -         -         -         -         -         -         -         -         -
          4/ 5/78 <   .500  <   .500  <   .500  <   .500  <   .500  <   .500       -         -         -         -
          5/10/78      -         -         -         -         -         -         -         -         -         -
          6/ 8/78 <   .500  <   .500  <   .500  <   .500  <   .500  <   .500  <   .500  <   .500       -         -
          7/12/78      -         -         -         -         -         -         -         -         -         -
          8/ 9/78 <   .500  <   .500  <   .500  <   .500  <   .500  <   .500       -         -         -         -
          9/13/78      -         -         -         -         -         -         -         -         -         -
         10/12/78      -    <   .500  <   .500  <   .500  <   .500  <   .500       -         -         -         -
         11/14/78      -         -         -         -         -         -         -         -         -         -
         12/ 5/78 <   .500  <   .500  <   .500  <   .500  <   .500  <   .500       -         -         -         -
# OBS                    9        10        10         6         6         6         3         3         2         2
MEAN                  .011      .021      .060      .000      .000      .000      .007      .006      .035      .330
STD DEV               .018      .028      .112      .000      .000      .000      .006      .005      .007      .000

BOD 5     8/14/75      2.0       1.0       3.0       -         -         -         -         -         -         -
          9/21/75      -    <    1.0       1.0       -         -         -         -         -         -         -
# OBS                    1         2         2       -         -         -         -         -         -         -
MEAN                   2.0        .5       2.0       -         -         -         -         -         -         -
STD DEV                 .0        .7       1.4       -         -         -         -         -         -         -

TC        8/14/75      68.      180.       63.       -         -         -         -         -         -         -
          9/21/75      -        170.       61.       -         -         -         -         -         -         -
# OBS                    1         2         2       -         -         -         -         -         -         -
MEAN                   68.      175.       62.       -         -         -         -         -         -         -
STD DEV                 0.        7.        1.       -         -         -         -         -         -         -

CN        8/14/75 <   .005  <   .005  <   .005       -         -         -         -         -         -         -
          9/21/75      -    <   .005  <   .005       -         -         -         -         -         -         -
          1/11/78      -         -         -         -         -         -         -         -         -         -
          2/16/78      -         -         -         -         -         -         -         -         -         -
          3/10/78 <   .005  <   .005  <   .005  <   .005  <   .005  <   .005       -         -         -         -
          4/ 5/78      -         -         -         -         -         -         -         -         -         -
          5/10/78      -         -         -         -         -         -         -         -         -         -
          6/ 8/78 <   .005  <   .005  <   .005  <   .005  <   .005  <   .005       -         -         -         -
          7/12/78      -         -         -         -         -         -         -         -         -         -
          8/ 9/78      -         -         -         -         -         -         -         -         -         -
          9/13/78      -    <   .005  <   .005  <   .005  <   .005  <   .005       -         -         -         -
         10/12/78      -         -         -         -         -         -         -         -         -         -
         11/14/78      -         -         -         -         -         -         -         -         -         -
         12/ 5/78 <   .005  <   .005  <   .005  <   .005  <   .005  <   .005       -         -         -         -
# OBS                    4         6         6         4         4         4       -         -         -         -
MEAN                  .000      .000      .000      .000      .000      .000       -         -         -         -
STD DEV               .000      .000      .000      .000      .000      .000       -         -         -         -
```

```
                                                 PERMITTED SANITARY LANDFILL
                                            MONITOR POINTS
PARAM    DATE       1        2        3        4        5        6        7        8        9       10

COLOR   8/14/75      5.      10.      15.      -        -        -        -        -        -        -
        9/21/75    -         10.       5.      -        -        -        -        -        -        -
# OBS                1        2        2       -        -        -        -        -        -        -
MEAN                 5.      10.      10.      -        -        -        -        -        -        -
STD DEV              0.       0.       7.      -        -        -        -        -        -        -

HARD    8/14/75    526.0    754.0    394.0     -        -        -        -        -        -        -
        9/21/75    -        864.0    356.0     -        -        -        -        -        -        -
        1/11/78     49.0    570.0    100.0    232.0    250.0    140.0    118.0    116.0     -        -
        2/16/78    540.0    460.0    102.0    162.0    226.0     46.0     -        -        -        -
        3/10/78    541.0    398.0     82.0    245.0    245.0    138.0     -        -        -        -
        4/ 5/78    520.0    380.0     48.5    120.0    106.0    122.0     -        -        -        -
        5/10/78    510.0    536.0     46.0    120.0    230.0    136.0     -        -        -        -
        6/ 8/78    510.0    640.0     46.0    218.0    232.0    146.0     -        -        -        -
        7/12/78    530.0    660.0     66.0    216.0    218.0    170.0     -        -        -        -
        8/ 9/78    486.0    654.0     71.0    219.0    211.0    158.0     -        -        -        -
        9/13/78    -        648.0     70.0    214.0    193.0    163.0     -        -        -        -
       10/12/78    -        700.0     94.0    210.0    200.0    240.0     -        -        -        -
       11/14/78    -        750.0     90.0    212.0    245.0    122.0     -       188.0     -        -
       12/ 5/78    400.0    730.0     54.0    168.0    156.0    160.0     -        -        -        -
# OBS               10       14       14       12       12       12        1        2     -        -
MEAN               461.2    624.6    115.7    194.7    209.3    145.1    118.0    152.0     -        -
STD DEV            150.6    141.0    111.8     41.9     42.0     44.1       .0     50.9     -        -

PHENOL  8/14/75    .002 <   .001 <   .001      -        -        -        -        -        -        -
        9/21/75    -        .005     .002      -        -        -        -        -        -        -
        1/11/78    -        -        -         -        -        -        -        -        -        -
        2/16/78 <  .020 <   .020 <   .020 <   .020 <   .020     .033      -        -        -        -
        3/10/78    -        -        -         -        -        -        -        -        -        -
        4/ 5/78 <  .020 <   .020 <   .020 <   .020 <   .020 <   .020      -        -        -        -
        5/10/78    -        -        -         -        -        -        -        -        -        -
        6/ 8/78 <  .020 <   .020 <   .020 <   .020 <   .020 <   .020      -        -        -        -
        7/12/78    -        -        -         -        -        -        -        -        -        -
        8/ 9/78 <  .020     .060     .025     .060 <   .020 <   .020      -        -        -        -
        9/13/78    -        -        -         -        -        -        -        -        -        -
       10/12/78    -     <  .010 <   .010 <   .010 <   .010 <   .010      -        -        -        -
       11/14/78    -        -        -         -        -        -        -        -        -        -
       12/ 5/78 <  .010 <   .010 <   .010 <   .010     .014     .055      -        -        -        -
# OBS                6        8        8        6        6        6      -        -        -        -
MEAN               .000     .008     .003     .010     .002     .015      -        -        -        -
STD DEV            .001     .021     .009     .024     .006     .024      -        -        -        -

SET S   8/14/75     .30      .20      .20      -        -        -        -        -        -        -
        9/21/75    -         .30     1.00      -        -        -        -        -        -        -
# OBS                1        2        2       -        -        -        -        -        -        -
MEAN                .30      .25      .60      -        -        -        -        -        -        -
STD DEV             .00      .07      .57      -        -        -        -        -        -        -

SS      8/14/75   94.00    16.00    74.00      -        -        -        -        -        -        -
        9/21/75    -      156.00   270.00      -        -        -        -        -        -        -
# OBS                1        2        2       -        -        -        -        -        -        -
MEAN              94.00    86.00   172.00      -        -        -        -        -        -        -
STD DEV             .00    98.99   138.59      -        -        -        -        -        -        -

AS      8/14/75 <  .030 <   .030 <   .030      -        -        -        -        -        -        -
        9/21/75    -     <  .030 <   .030      -        -        -        -        -        -        -
```

Reproduced from
best available copy.

```
           1/11/78     -       -       -       -       -       -       -       -       -       -
           2/16/78     -       -       -       -       -       -       -       -       -       -
           3/10/78 <  .005 <  .005    .012 <  .005 <  .005    .005     -       -       -       -
           4/ 5/78     -       -       -       -       -       -       -       -       -       -
           5/10/78     -       -       -       -       -       -       -       -       -       -
           6/ 8/78 <  .005 <  .005 <  .005 <  .005 <  .005 <  .005     -       -       -       -
           7/12/78     -       -       -       -       -       -       -       -       -       -
           8/ 9/78     -       -       -       -       -       -       -       -       -       -
           9/13/78     -    <  .005 <  .005 <  .005 <  .005 <  .005     -       -       -       -
          10/12/78     -       -       -       -       -       -       -       -       -       -
          11/14/78     -       -       -       -       -       -       -       -       -       -
          12/ 5/78    .016    .004    .005    .002    .003    .001     -       -       -       -
# OBS                    4       6       6       4       4       4     -       -       -       -
MEAN                  .004    .001    .003    .000    .001    .002     -       -       -       -
STD DEV               .008    .003    .005    .001    .001    .002     -       -       -       -

B          8/14/75 <    .2 <    .2      .6     -       -       -       -       -       -       -
           9/21/75     -    <   .2      .6     -       -       -       -       -       -       -
# OBS                    1       2       2     -       -       -       -       -       -       -
MEAN                    .0      .0      .6     -       -       -       -       -       -       -
STD DEV                 .0      .0      .0     -       -       -       -       -       -       -
```

```
                                                      PERMITTED SANITARY LANDFILL
                                                MONITOR POINTS
PARAM        DATE         1         2         3         4         5         6         7         8         9        10

BA        1/11/78      .170      .230     1.230      .360      .220    < .050    < .050    < .050         -         -
          2/16/78    < .100    < .100    < .100    < .100      .200    < .100         -         -         -         -
          3/10/78      .200    < .100      .300      .300      .300      .200         -         -         -         -
          4/ 5/78      .200      .200      .400      .400      .300    < .100         -         -         -         -
          5/10/78      .200      .200      .300      .400      .300      .200         -         -         -         -
          6/ 8/78    < .100    < .100    < .100      .300    < .100    < .100         -         -         -         -
          7/12/78    < .100    < .100      .300      .300    < .100    < .100         -         -         -         -
          8/ 9/78      .200      .200     2.050      .600    < .100      .100         -         -         -         -
          9/13/78         -      .300      .500      .600      .200      .100         -         -         -         -
         10/12/78         -      .300      .500      .500      .300      .100         -         -         -         -
         11/14/78         -      .200      .500      .100      .200      .100         -         -         -         -
         12/ 5/78      .100      .200      .500      .300      .100    < .100         -         -         -         -
# OBS                     9        12        12        12        12        12         1         1         -         -
MEAN                   .119      .153      .548      .347      .177      .067      .000      .000         -         -
STD DEV                .095      .118      .567      .178      .122      .078      .000      .000         -         -

CA        1/17/75    136.00    175.00     32.00         -         -         -     47.00     37.00     73.00     73.00
          4/12/75    120.00    185.00     81.00         -         -         -     37.00     32.00     72.00     74.60
          7/19/75         -         -         -         -         -         -         -         -         -         -
          8/14/75    145.00    200.00    110.00         -         -         -         -         -         -         -
          9/21/75    135.00    190.00    100.00         -         -         -         -         -         -         -
# OBS                     4         4         4         -         -         -         2         2         2         2
MEAN                 134.00    187.50     80.75         -         -         -     42.00     34.50     72.50     73.50
STD DEV               10.36     10.41     34.65         -         -         -      7.07      3.54       .71       .71

CD        1/17/75    < .010    < .010    < .010         -         -         -    < .010    < .010    < .010    < .010
          4/12/75    < .010    < .010    < .010         -         -         -    < .010    < .010    < .010    < .010
          7/19/75         -         -         -         -         -         -         -         -         -         -
          8/14/75    < .010    < .010    < .010         -         -         -         -         -         -         -
          9/21/75    < .010    < .010    < .010         -         -         -         -         -         -         -
          1/11/78      .008      .006      .005      .003      .004    < .002    < .002      .003         -         -
          2/16/78    < .001    < .001    < .001      .001    < .001    < .001         -         -         -         -
          3/10/78    < .001    < .001    < .001    < .001    < .001    < .001         -         -         -         -
          4/ 5/78    < .001    < .001    < .001      .002    < .001    < .001         -         -         -         -
          5/10/78      .001      .001      .001      .005      .001      .001         -         -         -         -
          6/ 8/78    < .001      .001    < .001      .002    < .001    < .001         -         -         -         -
          7/12/78    < .001    < .001      .001    < .001    < .001    < .001         -         -         -         -
          8/ 9/78    < .001    < .001    < .001      .002    < .001    < .001         -         -         -         -
          9/13/78         -    < .001    < .001    < .001    < .001    < .001         -         -         -         -
         10/12/78         -      .002    < .001      .003    < .001    < .001         -         -         -         -
         11/14/78         -      .001      .001      .001      .002      .001         -         -         -         -
         12/ 5/78      .004      .004      .003    < .001      .002    < .001         -         -         -         -
# OBS                    13        16        16        12        12        12         3         3         2         2
MEAN                   .001      .001      .001      .002      .001      .000      .000      .001      .000      .000
STD DEV                .002      .002      .001      .002      .001      .000      .000      .002      .000      .000

CR        1/11/78      .030      .030      .030    < .020    < .020    < .020    < .020    < .020         -         -
          2/16/78    < .005      .019      .008      .011    < .005      .019         -         -         -         -
          3/10/78      .006      .006      .016    < .005    < .005      .008         -         -         -         -
          4/ 5/78    < .005      .018      .014    < .005    < .005      .008         -         -         -         -
          5/10/78    < .005    < .005    < .005    < .005    < .005    < .005         -         -         -         -
          6/ 8/78      .008    < .005    < .005      .008      .006    < .005         -         -         -         -
          7/12/78      .006    < .005      .008    < .005    < .005    < .005         -         -         -         -
          8/ 9/78      .030      .022      .026      .015      .021      .019         -         -         -         -
          9/13/78         -      .040      .065      .040    < .005      .006         -         -         -         -
         10/12/78         -      .016      .006    < .005    < .005      .007         -         -         -         -
```

```
          11/14/78     -   < .005 < .005    .009 < .005 < .005     -       -       -       -
          12/ 5/78   .023    .024   .014    .008   .031   .018     -       -       -       -
# OBS                   9      12     12      12     12     12      1       1      -       -
MEAN                 .011    .015   .016    .008   .005   .007   .000    .000      -       -
STD DEV              .013    .013   .018    .012   .010   .008   .000    .000      -       -

F          8/14/75    .21     .12    .56     -      -      -       -       -       -       -
           9/21/75     -      .07    .54     -      -      -       -       -       -       -
# OBS                   1       2      2     -      -      -       -       -       -       -
MEAN                  .21     .09    .55     -      -      -       -       -       -       -
STD DEV               .00     .04    .01     -      -      -       -       -       -       -

HG         8/14/75 < .0005 < .0005 < .0005   -      -      -       -       -       -       -
           9/21/75     -   < .0005 < .0005   -      -      -       -       -       -       -
           1/11/78  .0005 < .0005   .0006 < .0005 < .0005   .0006 < .0005 < .0005    -       -
           2/16/78  .0008   .0005   .0008   .0004   .0005   .0007    -       -       -       -
           3/10/78 < .0002 < .0002 < .0002 < .0002 < .0002 < .0002   -       -       -       -
           4/ 5/78 < .0002 < .0002 < .0002 < .0002 < .0002 < .0002   -       -       -       -
           5/10/78 < .0002 < .0002 < .0002 < .0002 < .0002 < .0002   -       -       -       -
           6/ 8/78  .0002   .0011   .0006 < .0002 < .0002   .0008    -       -       -       -
           7/12/78  .0003 < .0002   .0004 < .0002   .0002   .0002    -       -       -       -
           8/ 9/78 < .0002 < .0002 < .0002 < .0002 < .0002 < .0002   -       -       -       -
           9/13/78     -     .0002 < .0002   .0007 < .0002   .0003    -       -       -       -
          10/12/78     -   < .0002   .0003 < .0002 < .0002 < .0002   -       -       -       -
          11/14/78     -     .0020   .0030 < .0020   .0020 < .0020   -       -       -       -
          12/ 5/78 < .0002 < .0002 < .0002 < .0002 < .0002 < .0002   -       -       -       -
# OBS                  10      14      14      12      12      12      1       1      -       -
MEAN                .0002   .0003   .0004   .0001   .0002   .0002   .0000   .0000     -       -
STD DEV             .0003   .0006   .0008   .0002   .0006   .0003   .0000   .0000     -       -

MG         1/17/75  35.00   41.00    9.30     -       -       -     17.00   14.00   23.00   24.00
           4/12/75  27.00   33.00   21.00     -       -       -     14.00   12.00   21.00   21.00
           7/19/75    -       -       -       -       -       -       -       -       -       -
           8/14/75  40.00   62.00   29.00     -       -       -       -       -       -       -
           9/21/75  38.00   45.00   31.00     -       -       -       -       -       -       -
# OBS                   4       4       4     -       -       -        2       2       2       2
MEAN                35.00   45.25   22.58     -       -       -     15.50   13.00   22.00   22.50
STD DEV              5.72   12.23    9.85     -       -       -      2.12    1.41    1.41    2.12
```

```
                                                 PERMITTED SANITARY LANDFILL
                                             MONITOR POINTS
PARAM    DATE        1        2        3        4        5        6        7        8        9       10

NI       1/17/75 <  .01 <    .01 <    .01       -        -        -   <    .01 <    .01 <    .01 <    .01
         4/12/75    .42     2.80    29.00       -        -        -   <    .01 <    .01      .17 <    .01
         7/19/75    -        -        -         -        -        -        -        -        -        -
         8/14/75 <  .03 <    .03 <    .03       -        -        -        -        -        -        -
         9/21/75 <  .03 <    .03 <    .03       -        -        -        -        -        -        -
# OBS               4        4        4         -        -        -        2        2        2        2
MEAN                .10      .70     7.25       -        -        -       .00      .00      .08      .00
STD DEV             .21     1.40    14.50       -        -        -       .00      .00      .12      .00

SE       8/14/75 < .010 <   .010 <   .010       -        -        -        -        -        -        -
         9/21/75    -        -    <  .010       -        -        -        -        -        -        -
         1/11/78 < .010 <   .010 <   .010 <   .010 <   .010 <   .010 <   .010 <   .010       -        -
         2/16/78   .001     .001     .005 <   .001 <   .001 <   .001       -        -        -        -
         3/10/78 < .002 <   .002 <   .002 <   .002 <   .002 <   .002       -        -        -        -
         4/ 5/78 < .010     .020 <   .010     .010     .010     .020       -        -        -        -
         5/10/78   .075     .015     .010     .006     .017     .009       -        -        -        -
         6/ 8/78   .006     .011 <   .001 <   .001 <   .001 <   .001       -        -        -        -
         7/12/78 < .001 <   .001 <   .001 <   .001 <   .001 <   .001       -        -        -        -
         8/ 9/78 < .001 <   .001 <   .001 <   .001 <   .001 <   .001       -        -        -        -
         9/13/78    -       .002 <   .003 <   .003 <   .003 <   .003       -        -        -        -
        10/12/78    -    <  .001 <   .001 <   .001 <   .001 <   .001       -        -        -        -
        11/14/78    -       .003     .014 <   .001     .006 <   .001       -        -        -        -
        12/ 5/78 < .001     .001     .001 <   .001 <   .001 <   .001       -        -        -        -
# OBS                10       13       14       12       12       12        1        1       -        -
MEAN              .0082    .0040    .0021    .0013    .0027    .0024    .0000    .0000       -        -
STD DEV           .0235    .0068    .0045    .0032    .0055    .0061    .0000    .0000       -        -
```

APPENDIX E

CHEMICAL ANALYSES, PRESENT STUDY

KEY TO APPENDIX E

TEMP	Temperature, expressed in degrees centigrade
PH	pH, expressed in pH units
ALK	Alkalinity, total, as $CaCO_3$ *
ACID	Acidity, hot, as $CaCO_3$
SO4	Sulfate
SC	Specific conductance, expressed in micromhos/centimeter
CL	Chloride
TOC	Total organic carbon
COD	Chemical oxygen demand
TS	Total solids
TDS	Total dissolved solids
NO3-N	Nitrite plus nitrate nitrogen
NH3-N	Ammonia nitrogen
PO4-P	Phosphate, total
TKN	Total Kjeldahl nitrogen
CU	Copper
FE	Iron, total
MN	Manganese
NA	Sodium
PB	Lead
ZN	Zinc

* All analyses in milligrams/liter unless otherwise noted.
- Dashes indicate no data.
a Chemical interference-value excluded from the mean.
b Handling error-value excluded from the mean.
c Analytical error-value excluded from the mean.

```
                                                                MILLFILL
                                                                        MONITOR POINTS
PARAM         DATE        1        2        3        4        5        6        7        8        9       10       11       12       13       14       15

TEMP       5/17/78        -        -        -        -        -        -        -        -        -        -        -        -        -        -        -
          11/15/78        -        -        -        -        -        -        -        -        -        -        -        -        -        -        -
           1/22/79        -        -        -        -      7.0        -        -        -        -        -        -        -        -        -        -
           4/23/79     11.0     23.0     10.0     10.0      8.0        -     16.0        -      9.0      7.0        -      8.0      8.0        -        -
           7/24/79     14.0     23.0     12.0     12.0     12.0        -     24.0        -     12.0     13.0     12.0     13.0     13.0        -        -
# OBS                     2        2        2        2        3        -        2        -        2        2        1        2        2        -        -
MEAN                   12.5     23.0     11.0     11.0      9.0        -     20.0        -     10.5     10.0     12.0     10.5     10.5        -        -
STD DEV                 2.1       .0      1.4      1.4      2.6        -      5.7        -      2.1      4.2       .0      3.5      3.5        -        -

PH         5/17/78      6.4      6.3      6.9      7.6      6.9        -      8.1      8.6      7.4        -      7.1        -      7.6        -      7.0
          11/15/78      6.8      7.8      6.8      6.9      7.5        -      7.6        -      7.5      7.3        -      7.7        -        -        -
           1/22/79      7.8      6.5      6.8        -      6.7        -        -        -        -        -        -     11.0        -        -        -
           4/23/79      7.8      5.8      6.8      6.7      7.2        -      8.2        -      6.8      6.4        -     11.0      7.8        -        -
           7/24/79      7.1      6.8      6.8      6.7      6.8        -      8.0        -      6.6      7.1      7.4      7.1      7.3        -        -
# OBS                     5        5        5        4        5        -        4        1        4        3        2        4        3        -        1
MEAN                    7.2      6.6      6.8      7.0      7.0        -      8.0      8.6      7.1      6.9      7.3      9.4      7.6        -      7.0
STD DEV                  .6       .7       .0       .4       .3        -       .3       .0       .4       .5       .2      2.3       .3        -       .0

ALK        5/17/78        -        -        -        -        -        -        -        -        -        -        -        -        -        -        -
          11/15/78    280.0   4380.0    620.0    620.0    864.0        -    214.0        -    880.0    910.0        -    212.0        -        -        -
           1/22/79    320.0   3240.0    588.0    586.0    520.0        -        -        -    884.0    744.0        -   1160.0        -        -        -
           4/23/79    324.0   2660.0    750.0    650.0    620.0        -    292.0        -    820.0    910.0        -     60.0    420.0        -        -
           7/24/79    342.0   2430.0    680.0    660.0    910.0        -    168.0        -   1010.0    990.0    472.0    450.0    369.0        -        -
# OBS                     4        4        4        4        4        -        3        -        4        4        1        4        2        -        -
MEAN                  316.5   3177.5    659.5    629.0    728.5        -    224.7        -    898.5    888.5    472.0    470.5    394.5        -        -
STD DEV                26.1    871.1     71.4     33.3    188.5        -     62.7        -     79.9    110.3       .0    486.9     36.1        -        -

ACID       5/17/78        -        -        -        -        -        -        -        -        -        -        -        -        -        -        -
          11/15/78    -180.   -3000.    -640.    -640.    -872.        -    -212.        -    -936.    -540.        -    -294.        -        -        -
           1/22/79    -332.   -2720.    -602.    -598.    -536.        -        -        -    -796.    -838.        -   -1000.        -        -        -
           4/23/79    -358.   -2650.    -710.    -600.    -600.        -    -331.        -    -710.    -310.        -     -33.    -310.        -        -
           7/24/79    -359.   -1740.    -630.    -620.    -880.        -    -179.        -   -1020.    -960.    -527.    -564.    -314.        -        -
# OBS                     4        4        4        4        4        -        3        -        4        4        1        4        2        -        -
MEAN                  -307.   -2528.    -646.    -615.    -722.        -    -241.        -    -866.    -662.    -527.    -473.    -312.        -        -
STD DEV                 86.     546.      46.      20.     180.        -      80.        -     139.     216.       0.     409.       3.        -        -

SO4        5/17/78    160.0  12000.0    395.0    430.0    260.0        -    135.0    125.0    200.0        -    210.0        -    190.0        -    140.0
          11/15/78     73.0      5.3    280.0    240.0    260.0        -     68.0        -    100.0    280.0        -    160.0        -        -        -
           1/22/79     82.0  <   1.0    410.0    510.0    180.0        -        -        -    180.0    220.0        -     10.0        -        -        -
           4/23/79     83.0  <   1.0    290.0    360.0    180.0        -     92.0        -     85.0    170.0        -     30.0    130.0        -        -
           7/24/79     92.0  <   1.0    200.0    200.0    140.0        -     85.0        -    160.0    220.0    200.0     33.0    160.0        -        -
# OBS                     5        5        5        5        5        -        4        1        5        4        2        4        3        -        1
MEAN                   98.0   2401.1    315.0    348.0    200.0        -     95.0    125.0    145.0    222.5    205.0     59.0    160.0        -    140.0
STD DEV                35.3   5366.0     87.3    129.1     56.6        -     28.5       .0     50.2     45.0      7.1     67.1     30.0        -       .0

SC         5/17/78        -        -        -        -        -        -    740.0    450.0   1150.0        -   1100.0        -    700.0        -    600.0
          11/15/78    380.0  10000.0   1530.0   1430.0   2400.0        -    600.0        -   1500.0   1400.0        -    700.0        -        -        -
           1/22/79    600.0   7500.0   1400.0   1600.0   1025.0        -        -        -   1500.0   1400.0        -   3700.0        -        -        -
           4/23/79    575.0   5600.0   1300.0   1300.0   1200.0        -    650.0        -   1100.0    850.0        -    450.0    600.0        -        -
           7/24/79    700.0   5200.0   1400.0   1200.0   2500.0        -    600.0        -   1650.0   1150.0   1000.0    600.0    750.0        -        -
# OBS                     4        4        4        4        4        -        4        1        5        4        2        4        3        -        1
MEAN                  563.8   7075.0   1407.5   1382.5   1781.3        -    647.5    450.0   1380.0   1200.0   1050.0   1362.5    683.3        -    600.0
STD DEV               133.9   2193.0     94.1    172.9    664.4        -     66.0       .0    241.4    261.4     70.7   1561.7     76.4        -       .0

CL         5/17/78      3.6   1190.0  <   2.0      2.0      3.6        -     22.0     27.0  <   2.0        -     14.0        -  <   2.0        -    109.0
          11/15/78        -   1152.0     24.0     38.0    342.0        -     54.0        -     28.0    131.0        -     52.0        -        -        -
           1/22/79     15.0    900.0     22.0     22.0     82.0        -        -        -     35.0     60.0        -     30.0        -        -        -
           4/23/79     15.0    565.0     25.0     15.0     35.0        -     45.0        -     30.0      5.0        -     28.0      5.0        -        -
           7/24/79      2.6    460.0     47.0     53.0    460.0        -     41.0        -     66.0     47.0     91.0     56.0      2.1        -        -
# OBS                     4        5        5        5        5        -        4        1        5        4        2        4        3        -        1
MEAN                   9.05   853.40    24.00    26.00   184.52        -    40.50    27.00    31.80    60.75    52.50    41.50     2.37        -   109.00
STD DEV                6.88   332.61    16.05    19.91   207.91        -    13.48      .00    23.50    52.39    54.45    14.55     2.51        -      .00
```

```
                                                              HILLFILL
                                                                  MONITOR POINTS
PARAM    DATE        1         2        3        4        5      6       7       8        9       10       11       12       13     14      15

TOC      5/17/78      7.9    4420.0     13.0    179.0     46.0   -       2.4     6.3     19.0      -        1.7      -    <   1.0   -       1.0
        11/15/78      -       994.0     17.0      8.0     70.0   -      11.0      -      25.0     34.0      -       177.0     -      -       -
         1/22/79     10.0     205.0     13.0     14.0     15.0   -        -       -      16.0     22.0      -        90.0     -      -       -
         4/23/79     12.0     115.0     25.0     20.0     13.0   -       7.1      -      12.0     15.0      -        10.0     3.3    -       -
         7/24/79     35.0     132.0     27.0     30.0     61.0   -      12.0      -      40.0     19.0     14.0      10.0     3.6    -       -
# OBS                   4         5        5        5        5   -         4       1        5        4        2         4       3    -         1
MEAN                 16.2    1189.2     19.0     52.0     41.0   -       8.1     6.3     22.4     22.5      7.9      64.0     3.0    -       1.0
STD DEV              12.6    1841.6      6.6     71.9     26.1   -       4.4      .0     10.9      8.2      8.7      76.5     2.0    -        .0

COD      5/17/78     35.0  11000.0      43.0    300.0    100.0   -      16.0    20.0    141.0      -       20.0       -       9.0    -      12.0
        11/15/78      -      1400.0     23.0     19.0    235.0   -      39.0      -      20.0    155.0      -      1400.0     -      -       -
         1/22/79      3.0    1100.0     15.0     31.0     49.0   -        -       -      47.0     62.0      -       210.0     -      -       -
         4/23/79     28.0     300.0     60.0     40.0     30.0   -      20.0      -      32.0     64.0      -        40.0    24.0    -       -
         7/24/79     62.0     272.0     35.0     50.0    140.0   -      16.0      -      20.0     27.0     16.0      35.0     9.0    -       -
# OBS                   4         5        5        5        5   -         4       1        5        4        2         4       3    -         1
MEAN                32.20   2992.00    36.00   100.00   131.00   -     20.25   20.00    52.00    72.00    18.00    421.25   13.93    -     12.00
STD DEV             23.94   4906.57    19.74   105.30    86.83   -     10.90     .00    50.98    57.13     2.83    657.95    8.76    -       .00

TS       5/17/78      -         -        -        -        -     -        -       -        -        -        -         -       -      -       -
        11/15/78     904.     4860.     1100.    1179.    2301.  -      520.      -      1104.    1315.      -        857.     -      -       -
         1/22/79     904.     3552.     1360.    1574.    1130.  -        -       -      1206.    1270.      -       1197.     -      -       -
         4/23/79     886.     2844.     1262.    1294.     924.  -      610.      -       960.     800.      -        169.    965.    -       -
         7/24/79     964.     2607.     1067.    1016.    1050.  -      654.      -      1256.     953.     877.      379.    920.    -       -
# OBS                   4         4        4        4        4   -         3       -        4        4        1         4       2    -       -
MEAN                 915.     3468.     1221.    1267.    1365.  -      527.      -      1172.    1089.     877.      650.    937.    -       -
STD DEV               30.      996.      127.     237.     654.  -       68.      -       147.     240.       0.      465.     18.    -       -

TDS      5/17/78      -         -        -        -        -     -        -       -        -        -        -         -       -      -       -
        11/15/78      -       4370.     1040.    1030.    1981.  -      650.      -      1070.    1137.      -        946.     -      -       -
         1/22/79     650.     3100.     1170.    1365.     985.  -        -       -      1056.    1043.      -       1011.     -      -       -
         4/23/79     619.     2003.     1051.    1056.     795.  -      682.      -       844.     614.      -        147.    490.    -       -
         7/24/79     657.     2054.      973.     901.    1670.  -      626.      -      1170.     895.     769.      349.    493.    -       -
# OBS                   3         4        4        4        4   -         3       -        4        4        1         4       2    -       -
MEAN                 645.     3000.     1063.    1100.    1360.  -      653.      -      1036.     922.     769.      613.    492.    -       -
STD DEV               22.      916.       85.     174.     562.  -       28.      -       137.     240.       0.      370.      2.    -       -

NO3-N    5/17/78     .100     1.300     .430     .480     .510   -      .079    .051     .110      -       .300       -    <  .010   -      .320
        11/15/78      -        .710     .130     .120     .520   -      .300      -      .200     .310      -        .000     -      -       -
         1/22/79     .030      .740     .050     .310     .000   -        -       -      .030     .070      -        .190     -      -       -
         4/23/79     .120     1.200     .150     .200     .300   -      .070      -      .100     .230      -        .030 <  .010   -       -
         7/24/79     .290      .140     .200     .130     .080   -      .050      -      .100     .020     .140      .000 <  .010   -       -
# OBS                   4         5        5        5        5   -         4       1        5        4        2         4       3    -         1
MEAN                 .160      .818     .192     .248     .298   -      .130    .051     .128     .157     .220      .018    .000    -      .320
STD DEV              .102      .463     .144     .198     .229   -      .107    .000     .055     .135     .170      .079    .000    -      .000

NH3-N    5/17/78      -         -        -        -        -     -        -       -        -        -        -         -       -      -       -
        11/15/78      -      623.000    .420     .360     .360   -   <  .020      -      .060     .400      -    <   .020     -      -       -
         1/22/79     .020   410.000     .010     .950    1.300   -        -       -     1.000     .600      -       1.700     -      -       -
         4/23/79 <   .010    90.000     .030     .020     .050   -      .096      -   <  .010     .170      -        .010    .330    -       -
         7/24/79     .320    81.000    1.200     .900    7.000   -      .230      -     1.200    3.000     .350      .300    .690    -       -
# OBS                   3         4        4        4        4   -         3       -        4        4        1         4       2    -       -
MEAN                 .300   303.000     .515     .558    2.377   -      .100      -      .565    1.043     .350      .512    .510    -       -
STD DEV              .013   261.907     .591     .447    3.454   -      .116      -      .596    1.304     .000      .807    .255    -       -

PO4-P    5/17/78     .160      .500     .100    1.900     .900   -      .070    .070     .600      -       .040       -      .040    -      .040
        11/15/78    1.300      .090     .012     .010     .049   -      .013      -      .190     .014      -        .092     -      -       -
         1/22/79     .041      .500     .056     .064     .085   -        -       -      .200     .082      -        .052     -      -       -
         4/23/79     .006      .110     .007     .013     .010   -      .020      -      .077     .014      -        .029    .005    -       -
         7/24/79     .160      .280     .017     .013     .036   -   <  .003      -      .110     .014 <   .003      .042    .007    -       -
# OBS                   5         5        5        5        5   -         4       1        5        4        2         4       3    -         1
MEAN                 .333      .296     .050     .400     .232   -      .026    .070     .251     .031     .024      .054    .020    -      .040
STD DEV              .545      .227     .044     .839     .419   -      .031    .000     .245     .034     .026      .027    .020    -      .000
```

HILLFILL
MONITOR POINTS

PARAM	DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TKN	5/17/78	1.10	616.00	1.50	7.30	5.00	-	.39	.66	2.30	-	.21	-	.67	-	.98
	11/15/78	-	606.00	.92	.38	1.70	-	.26	-	1.40	.40	-	.60	-	-	-
	1/22/79	.92	610.00	.97	1.50	2.50	-	-	-	2.60	1.30	-	3.60	-	-	-
	4/23/79	1.20	220.00	1.70	1.40	2.10	-	.25	-	1.30	5.40	-	2.60	.67	-	-
	7/24/79	1.30	160.00	2.70	1.80	14.00	-	.53	-	2.60	4.00	.38	1.10	.87	-	-
# OBS		4	5	5	5	5	-	4	1	5	4	2	4	3	-	1
MEAN		1.13	442.40	1.56	2.48	5.10	-	.36	.66	2.00	2.80	.30	1.98	.74	-	.98
STD DEV		.24	232.04	.65	2.75	5.16	-	.13	.00	.64	2.30	.12	1.30	.12	-	.00
CU	5/17/78	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/15/78	.610	.020	.010	< .010	.010	-	.010	-	.010	< .010	-	< .010	-	-	-
	1/22/79	.020	.030	.020	.020	.010	-	-	-	.010	.020	-	.020	-	-	-
	4/23/79	< .010	< .010	< .010	< .010	< .010	-	< .010	-	< .010	< .010	-	< .010	< .010	-	-
	7/24/79	< .010	.010	< .010	< .010	< .010	-	< .010	-	< .010	< .010	< .010	< .010	< .010	-	-
# OBS		4	4	4	4	4	-	3	-	4	4	1	4	2	-	-
MEAN		.157	.015	.008	.005	.003	-	.003	-	.005	.003	.000	.005	.000	-	-
STD DEV		.302	.013	.010	.010	.006	-	.006	-	.006	.010	.000	.010	.000	-	-
FE	5/17/78	7.790	896.000	35.600	160.000	60.400	-	.250	.200	13.000	-	.100	-	.140	-	.720
	11/15/78	126.000	17.200	30.500	20.300	16.000	-	.050	-	.390	.310	-	.730	-	-	-
	1/22/79	10.600	50.600	30.500	30.600	19.700	-	-	-	1.070	1.660	-	.300	-	-	-
	4/23/79	.120	20.500	24.000	22.000	6.500	-	.060	-	.010	37.900	-	.060	.050	-	-
	7/24/79	.460	16.300	13.600	18.100	1.070	-	.020	-	.340	13.100	.010	.090	.030	-	-
# OBS		5	5	5	5	5	-	4	1	5	4	2	4	3	-	1
MEAN		28.996	201.720	28.440	53.160	20.734	-	.095	.200	3.042	13.142	.055	.300	.060	-	.720
STD DEV		54.420	388.368	9.950	62.696	23.378	-	.103	.000	5.575	17.282	.100	.340	.052	-	.000
MN	5/17/78	.110	5.300	2.710	6.050	1.030	-	.030	.010	.900	-	.010	-	.010	-	.030
	11/15/78	3.700	.100	1.030	1.600	.300	-	.020	-	1.000	.390	-	.100	-	-	-
	1/22/79	.100	.030	2.370	1.030	.390	-	-	-	1.050	.080	-	.030	-	-	-
	4/23/79	.040	.460	2.050	2.700	.020	-	.010	-	.940	2.160	-	< .010	.010	-	-
	7/24/79	.050	.790	2.390	2.940	.030	-	< .010	-	1.000	.790	< .010	.070	< .010	-	-
# OBS		5	5	5	5	5	-	4	1	5	4	2	4	3	-	1
MEAN		.800	1.340	2.270	3.120	.400	-	.015	.010	1.170	.855	.005	.070	.007	-	.030
STD DEV		1.613	2.209	.330	2.131	.421	-	.013	.000	.306	.821	.007	.079	.006	-	.000
NA	5/17/78	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/15/78	29.000	640.000	14.000	14.000	190.000	-	22.000	-	18.000	103.000	-	15.000	-	-	-
	1/22/79	17.000	403.000	13.000	14.000	36.000	-	-	-	24.000	37.000	-	37.000	-	-	-
	4/23/79	19.200	260.000	11.000	7.200	14.500	-	16.400	-	17.000	2.000	-	80.000	30.000	-	-
	7/24/79	20.000	209.000	12.000	13.000	220.000	-	15.000	-	10.000	18.000	30.000	10.000	30.000	-	-
# OBS		4	4	4	4	4	-	3	-	4	4	1	4	2	-	-
MEAN		20.300	380.500	12.500	12.050	115.125	-	17.800	-	19.450	40.200	30.000	35.500	30.000	-	-
STD DEV		5.380	191.493	1.291	3.200	104.067	-	3.704	-	3.035	44.148	.000	31.393	.000	-	-
PB	5/17/78	.070	.310	.090	.320	.170	-	.040	< .030	.090	-	.030	-	.080	-	< .030
	11/15/78	1.650	< .030	< .030	< .030	< .030	-	< .030	-	< .030	< .030	-	< .030	-	-	-
	1/22/79	< .030	< .030	< .030	< .030	< .030	-	-	-	< .030	< .030	-	< .030	-	-	-
	4/23/79	< .030	< .030	< .030	< .030	< .030	-	< .030	-	< .030	< .030	-	< .030	< .030	-	-
	7/24/79	< .030	< .030	< .030	< .030	< .030	-	< .030	-	< .030	< .030	< .030	< .030	< .030	-	-
# OBS		5	5	5	5	5	-	4	1	5	4	2	4	3	-	1
MEAN		.344	.062	.018	.064	.034	-	.010	.000	.018	.000	.015	.000	.013	-	.000
STD DEV		.731	.139	.040	.143	.076	-	.020	.000	.040	.000	.021	.000	.023	-	.000
ZN	5/17/78	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/15/78	3.300	.490	.490	.340	.100	-	.100	-	.080	.070	-	.120	-	-	-
	1/22/79	.120	.690	.140	.140	.100	-	-	-	.040	.060	-	.350	-	-	-
	4/23/79	.070	.170	.390	.140	.250	-	.220	-	.150	.290	-	.190	.960	-	-
	7/24/79	.050	.040	.090	.050	.080	-	.040	-	.040	.050	.330	.030	.420	-	-
# OBS		4	4	4	4	4	-	3	-	4	4	1	4	2	-	-
MEAN		.885	.347	.277	.167	.133	-	.120	-	.078	.117	.330	.172	.690	-	-
STD DEV		1.610	.291	.193	.123	.078	-	.092	-	.052	.115	.000	.135	.382	-	-

		MONITOR POINTS					BALEFILL	
PARAM	DATE	1	2	3	4	5	6	7
TEMP	11/15/78	5.0	10.0	-	8.0	10.0	9.0	9.0
	1/25/79	-	-	-	-	-	-	-
	4/26/79	10.0	8.0	7.0	8.0	8.0	8.0	8.0
	7/26/79	24.0	10.0	13.0	10.0	-	10.0	10.0
# OBS		3	3	2	3	2	3	3
MEAN		13.0	9.3	10.0	8.7	9.0	9.0	9.0
STD DEV		9.8	1.2	4.2	1.2	1.4	1.0	1.0
PH	11/15/78	7.2	7.5	-	7.0	7.6	6.8	7.1
	1/25/79	-	7.2	6.4	7.1	-	6.9	7.4
	4/26/79	6.0	7.3	5.8	7.4	8.2	7.8	7.2
	7/26/79	6.9	7.5	8.0	7.6	-	8.0	8.6
# OBS		3	4	3	4	2	4	4
MEAN		6.7	7.4	6.7	7.3	7.9	7.4	7.6
STD DEV		.6	.2	1.1	.3	.4	.6	.7
ALK	11/15/78	2600.0	640.0	-	262.0	136.0	280.0	266.0
	1/25/79	-	218.0	466.0	254.0	-	250.0	224.0
	4/26/79	2770.0	230.0	436.0	256.0	32.0	254.0	231.0
	7/26/79	2820.0	392.0	346.0	264.0	-	243.0	231.0
# OBS		3	4	3	4	2	4	4
MEAN		2730.0	370.0	416.0	259.0	84.0	256.8	238.0
STD DEV		115.3	196.7	62.4	4.8	73.5	16.2	19.0
ACID	11/15/78	-2300.	-480.	-	-286.	-128.	-284.	-294.
	1/25/79	-	-240.	-496.	-288.	-	-294.	-256.
	4/26/79	-2520.	-266.	-488.	-261.	-19.	-260.	-233.
	7/26/79	-2840.	-363.	-385.	-295.	-	-222.	-253.
# OBS		3	4	3	4	2	4	4
MEAN		-2553.	-337.	-456.	-283.	-74.	-265.	-259.
STD DEV		272.	109.	62.	15.	77.	32.	25.
SO4	11/15/78	2040.0	2.7	-	24.0	11.0	21.0	23.0
	1/25/79	-	14.0	14.0	34.0	-	24.0	28.0
	4/26/79	2.8	3.6	9.2	36.0	95.0	18.0	23.0
	7/26/79	2.6	1.0	1.0	36.0	-	16.0	25.0
# OBS		3	4	3	4	2	4	4
MEAN		2040.0	5.1	8.1	32.5	53.0	19.8	24.8
STD DEV		.0	6.1	6.6	5.7	59.4	3.5	2.4
SC	11/15/78	6630.0	910.0	-	480.0	780.0	510.0	520.0
	1/25/79	-	400.0	1000.0	500.0	-	450.0	425.0
	4/26/79	6000.0	475.0	850.0	450.0	250.0	450.0	425.0
	7/26/79	6000.0	775.0	575.0	450.0	-	360.0	400.0
# OBS		3	4	3	4	2	4	4
MEAN		6210.0	640.0	808.3	470.0	515.0	442.5	442.5
STD DEV		363.7	242.2	215.5	24.5	374.8	61.8	53.0
CL	11/15/78	776.0	45.0	-	15.0	21.0	16.0	19.0
	1/25/79	-	20.0	75.0	10.0	-	7.5	10.0
	4/26/79	850.0	24.0	50.0	3.5	5.0	2.0	6.5
	7/26/79	625.0	70.0	5.0	5.0	-	5.0	5.0
# OBS		3	4	3	4	2	4	4
MEAN		750.33	39.75	43.33	8.38	13.00	7.63	10.13
STD DEV		114.67	22.95	35.47	5.22	11.31	6.02	6.28

```
                                                                            BALEFILL
                                                   MONITOR POINTS
PARAM        DATE         1         2         3         4         5         6         7

TOC      11/15/78     452.0      37.0         -       6.8       3.7       8.0       5.4
          1/25/79         -      12.0      29.0       8.3         -       5.9       8.5
          4/26/79     206.0       5.5      21.0       3.7       3.2       7.1       6.3
          7/26/79     614.0      80.0      29.0      13.0         -      14.0      14.0
# OBS                     3         4         3         4         2         4         4
MEAN                  424.0      33.6      26.3       7.9       3.4       8.8       8.6
STD DEV               205.4      33.8       4.6       3.9        .4       3.6       3.9

COD      11/15/78     890.0      85.0         -      12.0       3.9       3.9       3.9
          1/25/79         -      23.0      54.0      15.0         -       4.0       4.0
          4/26/79     834.0      37.0      70.0      17.0      23.0      19.0      25.0
          7/26/79    1176.0     141.0      27.0      16.0         -      12.0      20.0
# OBS                     3         4         3         4         2         4         4
MEAN                 966.67     71.50     50.33     15.00     13.45      9.73     13.23
STD DEV              183.44     53.40     21.73      2.16     13.51      7.26     10.90

TS       11/15/78     4117.      621.         -      333.      196.      385.      577.
          1/25/79         -      290.      600.      298.         -      284.      306.
          4/26/79     4194.      298.      575.      339.      226.      305.      340.
          7/26/79     3835.      657.      389.      346.         -      283.      352.
# OBS                     3         4         3         4         2         4         4
MEAN                  4049.      467.      521.      329.      211.      314.      394.
STD DEV                189.      200.      115.       21.       21.       48.      124.

TDS      11/15/78     3786.      520.         -      304.      122.      292.      338.
          1/25/79         -      274.      598.      296.         -      278.      302.
          4/26/79     4005.      280.      534.      314.      201.      303.      328.
          7/26/79     3612.      620.      365.      329.         -      251.      290.
# OBS                     3         4         3         4         2         4         4
MEAN                  3801.      424.      499.      311.      162.      281.      315.
STD DEV                197.      174.      120.       14.       56.       22.       22.

NO3-N    11/15/78      .290      .120         -      .230      .120      .480     7.300
          1/26/79         -      .080 <    .010      .150         -      .030     5.900
          4/26/79 <    .010 <    .010      .050      .090 <    .010      .020     4.500
          7/26/79      .030      .250 <    .010      .020         -      .010     3.500
# OBS                     3         4         3         4         2         4         4
MEAN                   .107      .112      .017      .122      .060      .135     5.300
STD DEV                .159      .104      .029      .089      .085      .230     1.657

NH3-N    11/15/78   180.000      .200         -      .050 <    .020 <    .020      .090
          1/25/79         -      .140     7.800      .100         -      .090      .090
          4/26/79   250.000 <    .020      .780      .030      .100 <    .020      .040
          7/26/79   110.000 <    .020      .130 <    .020         - <    .020 <    .020
# OBS                     3         4         3         4         2         4         4
MEAN                180.000      .085     2.903      .045      .050      .022      .055
STD DEV              70.000      .101     4.253      .042      .071      .045      .044

PO4-P    11/15/78      .120      .036         -      .057      .017      .030      .110
          1/25/79         -      .041      .042      .120         -      .053      .031
          4/26/79      .310      .022      .025      .021      .120      .019      .057
          7/26/79      .550      .052      .032      .023         -      .034      .021
# OBS                     3         4         3         4         2         4         4
MEAN                   .320      .038      .033      .055      .068      .034      .055
STD DEV                .205      .012      .009      .046      .073      .014      .040
```

```
                                                                    BALEFILL
                                                    MONITOR POINTS
PARAM    DATE        1          2          3          4          5          6          7

TKN     11/15/78   231.00        .20       -           .09 <      .02 <      .02        .09
         1/25/79     -           .37       9.00        .38       -           .30        .48
         4/26/79   270.00        .43      10.00        .15        .19        .13        .68
         7/26/79   110.00 <      .02        .77 <      .02       -      <    .02 <      .02
# OBS                  3          4          3          4          2          4          4
MEAN               203.67        .25       6.59        .16        .09        .11        .31
STD DEV             83.43        .19       5.07        .16        .13        .14        .32

CU      11/15/78     .180       .020       -          .010       .010 <     .010       .050
         1/25/79     -      <   .010 <     .010 <     .010       -      <   .010 <     .010
         4/26/79     .540 <     .010 <     .010 <     .010 <     .010 <     .010 <     .010
         7/26/79     .150 <     .010 <     .010 <     .010       -      <   .010 <     .010
# OBS                  3          4          3          4          2          4          4
MEAN                 .290       .005       .000       .002       .005       .000       .012
STD DEV              .217       .010       .000       .005       .007       .000       .025

FE      11/15/78   20.500      8.300       -        10.000      2.410      4.890      3.420
         1/25/79     -          .060       .060       .180       -          .990       .050
         4/26/79   12.300       .120     20.100       .150       .100       .220       .090
         7/26/79    7.900       .740       .080       .050       -          .050       .060
# OBS                  3          4          3          4          2          4          4
MEAN               13.567      2.305      6.747      2.595      1.255      1.537       .905
STD DEV             6.395      4.008     11.564      4.937      1.633      2.272      1.677

MN      11/15/78     .310      1.270       -         1.100       .150      3.200       .470
         1/25/79     -          .170      1.650       .790       -         1.260       .090
         4/26/79     .280       .310      1.100       .540       .130       .600       .140
         7/26/79     .520      1.180      1.500       .370       -          .280       .060
# OBS                  3          4          3          4          2          4          4
MEAN                 .370       .732      1.417       .700       .140      1.335       .190
STD DEV              .131       .573       .284       .318       .014      1.309       .190

NA      11/15/78 640.000     16.000       -         9.000      3.300      6.000      5.200
         1/25/79     -         32.000     47.000      9.000       -         4.200      6.050
         4/26/79 550.000     25.100     38.300      5.410      3.550      4.050      5.620
         7/26/79 525.000     24.000      6.400      4.800       -         3.900      5.600
# OBS                  3          4          3          4          2          4          4
MEAN               571.667     24.275     30.567      7.052      3.425      4.538      5.617
STD DEV             60.484      6.555     21.376      2.263       .177       .983       .347

PB      11/15/78 <   .030 <     .030       -      <   .030 <     .030 <     .030 <     .030
         1/25/79     -      <   .030 <     .030 <     .030       -      <   .030 <     .030
         4/26/79 <   .030 <     .030 <     .030 <     .030 <     .030 <     .030 <     .030
         7/26/79 <   .030 <     .030 <     .030 <     .030       -      <   .030 <     .030
# OBS                  3          4          3          4          2          4          4
MEAN                 .000       .000       .000       .000       .000       .000       .000
STD DEV              .000       .000       .000       .000       .000       .000       .000

ZN      11/15/78     .320       .080       -          .130       .860       .120       .090
         1/25/79     -          .020      5.380       .010       -          .020       .030
         4/26/79     .150       .030      1.150       .050       .040       .230       .100
         7/26/79     .310       .030      1.640       .080       -          .120       .080
# OBS                  3          4          3          4          2          4          4
MEAN                 .260       .040      2.723       .067       .450       .123       .075
STD DEV              .095       .027      2.314       .051       .580       .086       .031
```

```
                                                                       MILLFILL
                                                  MONITOR POINTS
PARAM    DATE        1        2        3         4        5        6        7        8

TEMP   12/ 8/78    12.0     11.0     11.0       9.0       -      11.0     11.0       -
        2/14/79     7.0      4.0      -         3.0       -       6.0      4.0       -
        5/ 2/79     8.0      7.5      8.0       6.0       -       7.5      7.5     19.0
        8/ 2/79    15.0     11.0     10.0      14.0       -       9.0     11.0       -
# OBS                 4        4        3         4       -         4        4        1
MEAN               10.5      8.4      9.7       8.0       -       8.4      8.4     19.0
STD DEV             3.7      3.4      1.5       4.7       -       2.1      3.4       .0

PH     12/ 8/78     7.2      7.1      7.4       7.6       -       6.4      7.6       -
        2/14/79     6.9      7.2      7.1       7.3       -       6.8      7.2       -
        5/ 2/79     6.4      7.5      7.6       7.8       -       5.5      7.4      4.2
        8/ 2/79     8.2      7.6      7.5       7.2       -       7.9      7.6       -
# OBS                 4        4        4         4       -         4        4        1
MEAN                7.2      7.3      7.4       7.5       -       6.7      7.4      4.2
STD DEV              .8       .2       .2        .3       -       1.0       .2       .0

ALK    12/ 8/78   190.0    290.0     58.0      64.0       -     102.0    154.0       -
        2/14/79   179.0    441.0     61.0      31.0       -     162.0    192.0       -
        5/ 2/79   174.0    404.0     67.0      52.0       -     231.0    228.0   9450.0
        8/ 2/79   170.0    440.0     63.0     150.0       -     187.0    218.0       -
# OBS                 4        4        4         4       -         4        4        1
MEAN              178.3    393.8     62.3      74.3       -     170.5    198.0   9450.0
STD DEV             8.7     71.3      3.8      52.3       -      53.8     33.0       .0

ACID   12/ 8/78   -194.    -290.     -50.      -54.       -     -104.    -154.       -
        2/14/79   -196.    -495.     -68.      -15.       -     -176.    -212.       -
        5/ 2/79   -175.    -418.     -59.      -40.       -     -238.    -235.   -4360.
        8/ 2/79   -187.    -380.     -64.     -110.       -     -201.    -240.       -
# OBS                 4        4        4         4       -         4        4        1
MEAN              -188.    -396.     -60.      -55.       -     -180.    -210.   -4360.
STD DEV              9.      85.       8.       40.       -       57.      39.       0.

SO4    12/ 8/78    24.0      2.3     23.0      24.0       -      29.0     38.0       -
        2/14/79    20.0      7.7     21.0      28.0       -      27.0     41.0       -
        5/ 2/79    21.0      6.7     16.0      23.0       -      28.0     48.0   1010.0
        8/ 2/79    22.0     28.0     17.0      11.0       -      28.0     51.0     28.0
# OBS                 4        4        4         4       -         4        4        2
MEAN               21.8     11.2     19.3      21.5       -      28.0     44.5    519.0
STD DEV             1.7     11.5      3.3       7.3       -        .8      6.0    694.4

SC     12/ 8/78   440.0    540.0    140.0     140.0       -     270.0    340.0       -
        2/14/79   370.0    650.0    140.0     105.0       -     400.0    400.0       -
        5/ 2/79   400.0    700.0    140.0     120.0       -     400.0    450.0  14500.0
        8/ 2/79   350.0    600.0    150.0     145.0       -     350.0    450.0       -
# OBS                 4        4        4         4       -         4        4        1
MEAN              390.0    622.5    142.5     127.5       -     355.0    410.0  14500.0
STD DEV            39.2     68.5      5.0      18.5       -      61.4     52.3       .0

CL     12/ 8/78    16.0      7.6      5.1       5.1       -      14.0     14.0       -
        2/14/79    13.0     10.0     10.0      13.0       -      10.0      8.0       -
        5/ 2/79    15.0     10.0      5.0       5.0       -       6.0      5.0   1200.0
        8/ 2/79    16.0     25.0      3.0      25.0       -       6.6      4.5       -
# OBS                 4        4        4         4       -         4        4        1
MEAN              15.00    13.15     5.78     12.02       -      9.15     7.88  1200.00
STD DEV            1.41     7.49     2.48      9.43       -      3.68     4.37      .00
```

		MONITOR POINTS					MILLFILL		
PARAM	DATE	1	2	3	4	5	6	7	8
TOC	12/ 8/78	7.5	8.9	5.1	12.0	-	11.0	10.0	-
	2/14/79	9.6	16.0	2.8	1.4	-	8.5	7.6	-
	5/ 2/79	5.2	6.9	1.6	3.6	-	5.5	7.9	8350.0
	8/ 2/79	3.3	5.8	1.4	6.3	-	3.4	3.9	-
# OBS		4	4	4	4	-	4	4	1
MEAN		6.4	9.4	2.7	5.8	-	7.1	7.4	8350.0
STD DEV		2.7	4.6	1.7	4.6	-	3.3	2.5	.0
COD	12/ 8/78	3.9	12.0	3.9	7.8	-	16.0	31.0	-
	2/14/79	< 1.0	< 1.0	< 1.0	1.6	-	< 1.0	< 1.0	-
	5/ 2/79	5.8	7.8	15.0	3.9	-	12.0	3.9	23690.0
	8/ 2/79	12.0	15.0	23.0	12.0	-	12.0	12.0	-
# OBS		4	4	4	4	-	4	4	1
MEAN		5.43	8.70	10.48	6.32	-	10.00	11.73	23690.00
STD DEV		5.00	6.51	10.49	4.57	-	6.93	13.79	.00
TS	12/ 8/78	284.	350.	140.	390.	-	212.	270.	-
	2/14/79	258.	486.	95.	292.	-	249.	286.	-
	5/ 2/79	267.	478.	126.	199.	-	307.	349.	28870.
	8/ 2/79	274.	414.	105.	237.	-	270.	279.	-
# OBS		4	4	4	4	-	4	4	1
MEAN		271.	432.	117.	280.	-	260.	296.	28870.
STD DEV		11.	63.	20.	83.	-	40.	36.	0.
TDS	12/ 8/78	292.	313.	134.	222.	-	220.	264.	-
	2/14/79	246.	472.	92.	108.	-	239.	270.	-
	5/ 2/79	252.	462.	130.	126.	-	295.	314.	19500.
	8/ 2/79	231.	337.	92.	185.	-	245.	275.	-
# OBS		4	4	4	4	-	4	4	1
MEAN		255.	396.	112.	160.	-	250.	281.	19500.
STD DEV		26.	83.	23.	53.	-	32.	23.	0.
NO3-N	12/ 8/78	.870	.060	.220	.500	-	1.800	.590	-
	2/14/79	.770	.030	.160	.220	-	1.500	.770	-
	5/ 2/79	1.300	.120	.240	.530	-	1.200	1.000	2.800
	8/ 2/79	.670	.060	.090	.100	-	.540	1.100	-
# OBS		4	4	4	4	-	4	4	1
MEAN		.903	.067	.178	.337	-	1.260	.865	2.800
STD DEV		.277	.038	.068	.211	-	.539	.230	.000
NH3-N	12/ 8/78	< .020	< .020	.050	< .020	-	.030	< .020	-
	2/14/79	.070	.100	< .020	.090	-	.150	< .020	-
	5/ 2/79	.090	.100	.150	.140	-	.110	.140	120.000
	8/ 2/79	.050	.140	.500	.110	-	.100	.670	-
# OBS		4	4	4	4	-	4	4	1
MEAN		.053	.085	.175	.085	-	.097	.202	120.000
STD DEV		.039	.060	.225	.060	-	.050	.319	.000
PO4-P	12/ 8/78	.032	.020	.032	.190	-	.048	.040	-
	2/14/79	.007	.032	.005	.460	-	.049	.028	-
	5/ 2/79	< .003	< .003	.007	.089	-	.067	.006	1.800
	8/ 2/79	.026	.005	.032	.150	-	.049	.087	-
# OBS		4	4	4	4	-	4	4	1
MEAN		.016	.014	.019	.222	-	.052	.040	1.800
STD DEV		.015	.015	.015	.164	-	.010	.034	.000

```
                                                                      MILLFILL
                                                  MONITOR POINTS
PARAM     DATE         1          2          3          4          5          6          7          8

TKN     12/ 8/78      .03 <      .02        .05        .04        -          .08        .30        -
         2/14/79      .09        .11        .14        .55        -          .75        .06        -
         5/ 2/79      .10        .10        .08        .29        -          .19        .15     150.00
         8/ 2/79      .22        .35        .67        .85        -          .31       2.50        -
# OBS                  4          4          4          4         -           4          4          1
MEAN                  .11        .14        .23        .43        -          .33        .75     150.00
STD DEV               .08        .15        .29        .35        -          .29       1.17        .00

CU      12/ 8/78 <  .010 <     .010 <     .010 <     .010        -      <   .010 <     .010        -
         2/14/79 <  .010 <     .010 <     .010       .030        -      <   .010 <     .010        -
         5/ 2/79 <  .010 <     .010 <     .010 <     .010        -      <   .010 <     .010       .070
         8/ 2/79 <  .010 <     .010 <     .010 <     .010        -      <   .010 <     .010        -
# OBS                  4          4          4          4         -           4          4          1
MEAN                .000       .000       .000       .007        -          .000       .000       .070
STD DEV             .000       .000       .000       .015        -          .000       .000       .000

FE      12/ 8/78    .060     31.300       .120       .800        -          .340       .330        -
         2/14/79    .150      3.220 <     .010      8.600        -          .320       .250        -
         5/ 2/79 <  .010     41.500 <     .010      1.330        -          .220 <     .0103308.000
         8/ 2/79    .060     23.600 <     .010      1.300        -          .200       .210        -
# OBS                  4          4          4          4         -           4          4          1
MEAN                .067     24.905       .030      3.007        -          .270       .1983308.000
STD DEV             .062     16.209       .060      3.736        -          .070       .141       .000

MN      12/ 8/78    .010       .710       .020       .180        -          .150       .130        -
         2/14/79 <  .010       .640 <     .010       .130        -          .190       .030        -
         5/ 2/79 <  .010       .890 <     .010       .530        -          .150       .030    102.000
         8/ 2/79    .010       .620 <     .010       .470        -          .180 <     .010        -
# OBS                  4          4          4          4         -           4          4          1
MEAN                .005       .715       .005       .327        -          .167       .047    102.000
STD DEV             .006       .123       .010       .202        -          .021       .057       .000

NA      12/ 8/78   7.000      8.300      3.400      4.600        -         5.300      4.900        -
         2/14/79   6.100      8.000      3.000      2.600        -         4.300      3.700        -
         5/ 2/79   6.220      7.740      2.760      3.340        -         3.890      3.830    828.000
         8/ 2/79   6.220      7.090      3.070      3.950        -         3.900      4.410        -
# OBS                  4          4          4          4         -           4          4          1
MEAN               6.385      7.783      3.057      3.622        -         4.347      4.210    828.000
STD DEV             .414       .515       .264       .854        -          .663       .554       .000

PB      12/ 8/78 <  .030 <     .030 <     .030 <     .030        -      <   .030 <     .030        -
         2/14/79 <  .030 <     .030 <     .030 <     .030        -      <   .030 <     .030        -
         5/ 2/79 <  .030 <     .030 <     .030 <     .030        -      <   .030 <     .030 <     .030
         8/ 2/79 <  .030 <     .030 <     .030 <     .030        -      <   .030 <     .030        -
# OBS                  4          4          4          4         -           4          4          1
MEAN                .000       .000       .000       .000        -          .000       .000       .000
STD DEV             .000       .000       .000       .000        -          .000       .000       .000

ZN      12/ 8/78    .360       .100       .180       .210        -          .420       .210        -
         2/14/79   1.200       .240 <     .010       .090        -          .100       .060        -
         5/ 2/79    .370       .040       .030       .220        -          .050       .100     38.000
         8/ 2/79    .450       .040       .030       .020        -          .040 <     .010        -
# OBS                  4          4          4          4         -           4          4          1
MEAN                .595       .105       .060       .135        -          .152       .093     38.000
STD DEV             .405       .094       .081       .097        -          .180       .088       .000
```

```
                                                   STRIP MINE LANDFILL
                                                      MONITOR POINTS
PARAM   DATE             1        2        3        4        5        6        7        8        9       10

TEMP    12/ 2/78         -        -        -        -        -        -        -        -        -        -
         2/22/79       0.0      2.0        -        -      8.5      4.0      8.0        -        -      4.0
         5/ 9/79      15.0     18.0        -     16.0      9.0      8.0      9.0     25.0     21.0        -
         8/16/79      13.0     14.0        -     17.0      9.5     14.0      9.0        -     19.0        -
# OBS                    3        3        -        2        3        3        3        1        2        1
MEAN                   9.3     11.3        -     16.5      9.0      8.7      8.7     25.0     20.0      4.0
STD DEV                8.1      8.3        -       .7       .5      5.0       .6       .0      1.4       .0

PH      12/ 2/78         -        -        -        -        -        -        -        -        -        -
         2/22/79       7.8      7.4        -        -      7.2      7.8      7.4        -        -      7.3
         5/ 9/79       7.4      7.6        -      6.6      6.8      6.9      7.1      7.1      6.8        -
         8/16/79       7.4      7.5        -      7.2      7.3      7.6      7.4        -      7.4        -
# OBS                    3        3        -        2        3        3        3        1        2        1
MEAN                   7.5      7.5        -      6.9      7.1      7.4      7.3      7.1      7.1      7.3
STD DEV                 .2       .1        -       .4       .3       .5       .2       .0       .4       .0

ALK     12/ 2/78      78.0     98.0        -        -        -      8.0    188.0        -        -     20.0
         2/22/79      70.0     90.0        -        -    170.0     20.0    204.0        -        -    126.0
         5/ 9/79      97.0    122.0        -    318.0    311.0     17.0    347.0   5620.0     33.0        -
         8/16/79     121.0    135.0        -    328.0    474.0     33.0    233.0        -     47.0        -
# OBS                    4        4        -        2        3        4        4        1        2        2
MEAN                  91.5    111.3        -    323.0    318.3     19.5    243.0   5620.0     40.0     73.0
STD DEV               22.7     20.9        -      7.1    152.1     10.3     71.8       .0      9.9     75.0

ACID    12/ 2/78      -64.     -86.        -        -        -      24.    -182.        -        -       6.
         2/22/79      -71.     -94.        -        -    -192.     -14.    -229.        -        -    -137.
         5/ 9/79     -102.    -138.        -    -369.    -363.     -13.    -402.   -3000.     -27.        -
         8/16/79     -114.    -127.        -    -330.    -431.     -12.    -230.        -     -33.        -
# OBS                    4        4        -        2        3        4        4        1        2        2
MEAN                  -88.    -111.        -    -350.    -329.      -4.    -261.   -3000.     -30.     -66.
STD DEV                24.      25.        -      28.     123.      19.      97.       0.       4.     101.

SO4     12/ 2/78      85.0     85.0        -        -        -    100.0    425.0        -        -    115.0
         2/22/79      75.0     72.0        -        -    180.0     99.0    410.0        -        -     44.0
         5/ 9/79      80.0     84.0        -     93.0    190.0    110.0    310.0      6.8    170.0        -
         8/16/79     110.0     92.0        -    120.0    170.0     55.0    400.0        -     28.0        -
# OBS                    4        4        -        2        3        4        4        1        2        2
MEAN                  87.5     83.3        -    106.5    180.0     91.0    386.3      6.8     99.0     79.5
STD DEV               15.5      8.3        -     19.1     10.0     24.5     51.9       .0    100.4     50.2

SC      12/ 2/78     340.0    380.0        -        -        -    230.0   1100.0        -        -    300.0
         2/22/79     250.0    260.0        -        -    725.0    250.0   1075.0        -        -    400.0
         5/ 9/79     300.0    350.0        -    650.0    700.0    200.0   1000.0   9000.0    350.0        -
         8/16/79     400.0    450.0        -    850.0   1100.0    175.0    950.0        -    200.0        -
# OBS                    4        4        -        2        3        4        4        1        2        2
MEAN                 322.5    360.0        -    750.0    841.7    213.8   1031.3   9000.0    275.0    350.0
STD DEV               63.4     78.7        -    141.4    224.1     33.0     68.8       .0    106.1     70.7

CL      12/ 2/78       4.2      3.4        -        -        -      2.4     17.0        -        -      2.0
         2/22/79      12.0      9.0        -        -     20.0      2.5     22.0        -        -      7.5
         5/ 9/79       3.5      9.5        -     15.0   40.0 <      2.0      6.5 1100.0 <      2.0        -
         8/16/79       6.3      5.6        -      2.5      6.7      2.5     25.0        -      2.5        -
# OBS                    4        4        -        2        3        4        4        1        2        2
MEAN                  6.50     6.72        -     8.75    22.23     1.85    17.63  1100.00     1.25     4.75
STD DEV               3.85      .76        -     8.84    16.76     1.23     8.12      .00     1.77     3.89
```

STRIP MINE LANDFILL
MONITOR POINTS

PARAM	DATE	1	2	3	4	5	6	7	8	9	10
TOC	12/ 2/78	4.6	13.0	-	-	-	< 1.0	1.3	-	-	4.0
	2/22/79	3.2	1.7	-	-	7.6	1.4	6.8	-	-	3.0
	5/ 9/79	8.7	3.4	-	12.0	14.0	6.7	12.0	3070.0	8.6	-
	8/16/79	< 1.0	5.4	-	9.8	4.9	1.0	7.2	-	7.8	-
# OBS		4	4	-	2	3	4	4	1	2	2
MEAN		4.1	5.9	-	10.9	8.8	2.3	6.8	3070.0	8.2	3.5
STD DEV		3.6	5.0	-	1.6	4.7	3.0	4.4	.0	.6	.7
COD	12/ 2/78	3.9	47.0	-	-	-	< 1.0	3.9	-	-	7.9
	2/22/79	< 1.0	< 1.0	-	-	< 1.0	< 1.0	< 1.0	-	-	< 1.0
	5/ 9/79	12.0	16.0	-	24.0	20.0	9.9	20.0	9580.0	16.0 8	-
	8/16/79	19.0	23.0	-	31.0	31.0	16.0	23.0	-	141.0	-
# OBS		4	4	-	2	3	4	4	1	2	2
MEAN		8.73	21.50	-	27.50	17.33	6.48	11.73	9580.00	16.0	3.95
STD DEV		8.48	19.54	-	4.95	15.18	7.88	11.46	.00	.0	5.59
TS	12/ 2/78	241.	252.	-	-	-	157.	886.	-	-	199.
	2/22/79	215.	211.	-	-	513.	194.	907.	-	-	243.
	5/ 9/79	280.	304.	-	512.	669.	216.	1020.	12060.	293.	-
	8/16/79	371.	386.	-	565.	815.	140.	992.	-	148.	-
# OBS		4	4	-	2	3	4	4	1	2	2
MEAN		277.	288.	-	539.	666.	177.	951.	12060.	221.	221.
STD DEV		68.	75.	-	37.	151.	35.	65.	0.	103.	31.
TDS	12/ 2/78	194.	202.	-	-	-	113.	809.	-	-	181.
	2/22/79	98.	168.	-	-	444.	160.	812.	-	-	230.
	5/ 9/79	264.	303.	-	498.	631.	178.	705.	11145.	303.	-
	8/16/79	342.	347.	-	555.	793.	114.	940.	-	134.	-
# OBS		4	4	-	2	3	4	4	1	2	2
MEAN		225.	255.	-	527.	623.	141.	817.	11145.	219.	206.
STD DEV		104.	84.	-	40.	175.	33.	96.	0.	120.	35.
NO3-N	12/ 2/78	.610	.610	-	-	-	.250	.360	-	-	.060
	2/22/79	.750	.900	-	-	.210	.120	.090	-	-	8.800
	5/ 9/79	.260	.470	-	.060	.030	.030	< .010	.240	.010	-
	8/16/79	.740	.800	-	3.200	1.000	.120	.140	-	.360	-
# OBS		4	4	-	2	3	4	4	1	2	2
MEAN		.590	.695	-	1.630	.413	.130	.147	.240	.185	4.430
STD DEV		.229	.192	-	2.220	.516	.091	.153	.000	.247	6.180
NH3-N	12/ 2/78	< .020	< .020	-	-	-	< .020	< .020	-	-	.030
	2/22/79	.060	< .020	-	-	< .020	< .020	< .020	-	-	.300
	5/ 9/79	.040	.050	-	1.200	.090	.040	.050	150.000	.060	-
	8/16/79	.110	.080	-	2.300	.230	.080	.140	-	.130	-
# OBS		4	4	-	2	3	4	4	1	2	2
MEAN		.053	.032	-	1.750	.107	.030	.047	150.000	.095	.165
STD DEV		.046	.039	-	.778	.116	.038	.066	.000	.049	.191
PO4-P	12/ 2/78	.008	.012	-	-	-	.016	.040	-	-	.008
	2/22/79	.032	.029	-	-	.029	.030	.025	-	-	.016
	5/ 9/79	< .003	< .003	-	.005	.130	.016	.006	1.900	.017	-
	8/16/79	.005	.067	-	.018	.026	.005	.036	-	.011	-
# OBS		4	4	-	2	3	4	4	1	2	2
MEAN		.011	.027	-	.011	.062	.017	.027	1.900	.014	.012
STD DEV		.014	.029	-	.009	.059	.010	.015	.000	.004	.006

STRIP MINE LANDFILL
MONITOR POINTS

PARAM	DATE	1	2	3	4	5	6	7	8	9	10
TKN	12/ 2/78	< .02	< .02	-	-	-	< .02	.03	-	-	< .02
	2/22/79	.20	.42	-	-	3.30	.09	.09	-	-	1.30
	5/ 9/79	.10	.11	-	1.60	.83	.52	.71	180.00	.88	-
	8/16/79	.32	.48	-	2.70	.67	.19	.28	-	.52	-
# OBS		4	4	-	2	3	4	4	1	2	2
MEAN		.16	.25	-	2.15	1.60	.20	.28	180.00	.70	.65
STD DEV		.14	.23	-	.78	1.47	.23	.31	.00	.25	.92
CU	12/ 2/78	< .010	< .010	-	-	-	< .010	< .010	-	-	< .010
	2/22/79	< .010	.020	-	-	< .010	< .010	< .010	-	-	< .010
	5/ 9/79	< .010	< .010	-	< .010	.010	< .010	.010	.050	< .010	-
	8/16/79	< .010	< .010	-	< .010	< .010	< .010	< .010	-	< .010	-
# OBS		4	4	-	2	3	4	4	1	2	2
MEAN		.000	.005	-	.000	.003	.000	.002	.050	.000	.000
STD DEV		.000	.010	-	.000	.006	.000	.005	.000	.000	.000
FE	12/ 2/78	.120	.120	-	-	-	.910	.150	-	-	.060
	2/22/79	.140	.140	-	-	1.600	.400	.230	-	-	1.700
	5/ 9/79	.090	.070	-	7.030	5.700	.970	.160	96.800	.320	-
	8/16/79	.110	.150	-	3.900	8.000	2.150	.240	-	.050	-
# OBS		4	4	-	2	3	4	4	1	2	2
MEAN		.115	.120	-	5.465	5.100	1.107	.195	96.800	.185	.880
STD DEV		.021	.036	-	2.213	3.242	.741	.047	.000	.191	1.160
MN	12/ 2/78	.100	.190	-	-	-	.280	.090	-	-	.060
	2/22/79	.150	.210	-	-	.380	.380	.160	-	-	.920
	5/ 9/79	.030	.060	-	4.210	.710	.220	.910	7.740	.160	-
	8/16/79	.060	.230	-	5.700	.830	.180	.100	-	.010	-
# OBS		4	4	-	2	3	4	4	1	2	2
MEAN		.085	.172	-	4.955	.640	.265	.315	7.740	.085	.490
STD DEV		.052	.077	-	1.054	.233	.087	.398	.000	.106	.608
NA	12/ 2/78	5.900	8.420	-	-	-	1.080	2.680	-	-	1.300
	2/22/79	9.200	9.200	-	-	14.000	1.100	4.100	-	-	27.000
	5/ 9/79	7.000	10.500	-	64.000	51.000	1.500	15.000	1500.000	1.800	-
	8/16/79	7.200	8.700	-	64.000	85.000	.851	4.400	-	.636	-
# OBS		4	4	-	2	3	4	4	1	2	2
MEAN		7.325	9.205	-	64.000	50.000	1.133	6.545	1500.000	1.218	14.150
STD DEV		1.374	.922	-	.000	35.511	.270	5.686	.000	.823	18.173
PB	12/ 2/78	< .030	< .030	-	-	-	< .030	< .030	-	-	< .030
	2/22/79	< .030	< .030	-	-	< .030	< .030	< .030	-	-	< .030
	5/ 9/79	< .030	< .030	-	< .030	< .030	< .030	< .030	.080	< .030	-
	8/16/79	< .030	< .030	-	< .030	< .030	< .030	< .030	-	< .030	-
# OBS		4	4	-	2	3	4	4	1	2	2
MEAN		.000	.000	-	.000	.000	.000	.000	.080	.000	.000
STD DEV		.000	.000	-	.000	.000	.000	.000	.000	.000	.000
ZN	12/ 2/78	.090	.090	-	-	-	.110	.040	-	-	.030
	2/22/79	.050	< .010	-	-	.120	.250	.020	-	-	.170
	5/ 9/79	.100	.060	-	.030	.090	.270	.050	.910	.380	-
	8/16/79	.030	.080	-	.080	.200	.060	.200	-	.020	-
# OBS		4	4	-	2	3	4	4	1	2	2
MEAN		.067	.057	-	.055	.137	.172	.078	.910	.200	.100
STD DEV		.033	.040	-	.035	.057	.103	.083	.000	.255	.099

```
                                                         PERMITTED SANITARY LANDFILL
                                                   MONITOR POINTS
PARAM     DATE       1         2         3         4         5         6         7         8         9        10

TEMP   12/ 6/78    10.0      10.0      13.0      11.0      10.0      10.0       3.0       2.0        -         -
        2/13/79     7.0       7.0      11.0       7.0       8.0       8.0       0.0       0.0        -         -
        5/ 2/79     7.0       8.0      12.0       7.0       8.0       8.0       6.0       6.0        -         -
        8/ 1/79     9.5       9.0      12.0       9.0      10.0       9.5      14.0      14.0        -         -
# OBS                 4         4         4         4         4         4         4         4        -         -
MEAN                8.4       8.5      12.0       8.5       9.0       8.9       5.8       5.5        -         -
STD DEV             1.6       1.3        .8       1.9       1.2       1.0       6.0       6.2        -         -

PH     12/ 6/78     7.8       7.4       7.4       7.2       7.3       7.6       8.2       8.2        -         -
        2/13/79     6.8       6.9       7.4       7.2       7.4       7.7       7.8       7.8        -         -
        5/ 2/79     7.2       6.0       7.6       7.8       7.6       7.2       8.0       8.0        -         -
        8/ 1/79     7.6       7.2       7.6       6.6       7.2       7.7       7.7       8.0        -         -
# OBS                 4         4         4         4         4         4         4         4        -         -
MEAN                7.3       6.9       7.5       7.2       7.4       7.6       7.9       8.0        -         -
STD DEV              .4        .6        .1        .5        .2        .2        .2        .2        -         -

ALK    12/ 6/78   440.0     698.0     412.0     258.0     294.0     196.0       0.0C    116.0        -         -
        2/13/79   416.0     419.0     317.0     213.0     265.0     122.0     113.0     111.0        -         -
        5/ 2/79   443.0     467.0     372.0     227.0     292.0     179.0     115.0     106.0        -         -
        8/ 1/79   462.0     740.0     283.0     227.0     265.0     195.0     174.0     147.0        -         -
# OBS                 4         4         4         4         4         4         4         4        -         -
MEAN              440.3     581.0     346.0     231.3     279.0     173.0     134.0     120.0        -         -
STD DEV            18.9     161.5      57.3      19.0      16.2      34.9      34.7      18.5        -         -

ACID   12/ 6/78   -458.     -746.     -438.     -268.     -308.     -200.      208.C    -114.        -         -
        2/13/79   -486.     -491.     -364.     -247.     -310.     -139.     -130.     -129.        -         -
        5/ 2/79   -492.     -557.     -443.     -249.     -321.     -191.     -121.      -61.        -         -
        8/ 1/79   -426.     -670.     -277.     -225.     -260.     -188.     -166.     -189.        -         -
# OBS                 4         4         4         4         4         4         4         4        -         -
MEAN              -466.     -616.     -381.     -247.     -300.     -180.      139.     -123.        -         -
STD DEV             30.      114.       78.       18.       27.       27.       23.       53.        -         -

SO4    12/ 6/78    50.0      30.0       7.4      14.0       7.4      25.0    2200.0C     35.0        -         -
        2/13/79    46.0      33.0      15.0      22.0      10.0      38.0      31.0      26.0        -         -
        5/ 2/79    39.0      31.0       6.1      20.0       5.9      39.0      24.0      23.0        -         -
        8/ 1/79    39.0      30.0      41.0      48.0      35.0      41.0      52.0      50.0        -         -
# OBS                 4         4         4         4         4         4         4         4        -         -
MEAN               43.5      31.0      17.4      26.0      14.6      35.8      35.7      33.5        -         -
STD DEV             5.4       1.4      16.2      15.1      13.7       7.3      14.6      12.1        -         -

SC     12/ 6/78   960.0    1400.0    1600.0     400.0     600.0     480.0     220.0     220.0        -         -
        2/13/79   900.0     925.0    1400.0     400.0     900.0     425.0     250.0     300.0        -         -
        5/ 2/79  1000.0     925.0    1500.0     450.0     700.0     425.0     250.0     225.0        -         -
        8/ 1/79   900.0    1000.0    1450.0     380.0     850.0     450.0     400.0     325.0        -         -
# OBS                 4         4         4         4         4         4         4         4        -         -
MEAN              940.0    1062.5    1487.5     407.5     762.5     445.0     280.0     267.5        -         -
STD DEV            49.0     227.8      85.4      29.9     137.7      26.1      81.2      53.0        -         -

CL     12/ 6/78    68.0       9.0     214.0       7.0      49.0      24.0      42.0      31.0        -         -
        2/13/79    75.0      10.0     263.0      13.0     128.0      35.0      20.0      23.0        -         -
        5/ 2/79    80.0 <     2.0     280.0 <     2.0      52.0      36.0      14.0      12.0        -         -
        8/ 1/79     4.2       1.1     470.0       6.3     151.0      41.0      25.0      18.0        -         -
# OBS                 4         4         4         4         4         4         4         4        -         -
MEAN              56.80      5.02    306.75      6.57     95.00     34.00     25.25     21.00        -         -
STD DEV           35.41      5.20    112.37      5.32     52.25      7.16     12.04      8.04        -         -
```

```
                                                            PERMITTED SANITARY LANDFILL
                                                     MONITOR POINTS
PARAM    DATE        1         2         3         4         5         6         7         8         9        10

TOC     12/ 6/78    8.8      10.0       6.7       4.4       4.3       3.5       6.3       5.1       -         -
         2/13/79   14.0      15.0       8.2       6.1       6.8       4.1       6.3       4.9       -         -
         5/ 2/79   22.0      13.0      15.0       7.7       7.2       5.6       5.0       4.9       -         -
         8/ 1/79    2.5       2.6      17.0      10.0       5.5       7.0       7.3       6.1       -         -
# OBS                 4         4         4         4         4         4         4         4       -         -
MEAN               11.8      10.1      11.7       7.1       5.9       5.1       6.2       5.3       -         -
STD DEV             8.3       5.4       5.0       2.4       1.3       1.6        .9        .6       -         -

COD     12/ 6/78   16.0 <     1.0      55.0       3.9      20.0      12.0       7.8      12.0       -         -
         2/13/79 <  1.0 <     1.0       4.6 <     1.0       2.3       1.1 <     1.0 <     1.0       -         -
         5/ 2/79   12.0       2.2      18.0       4.1       8.0      10.0       8.0       6.1       -         -
         8/ 1/79    8.0 <     1.0      42.0      19.0      27.0      12.0       8.0       8.0       -         -
# OBS                 4         4         4         4         4         4         4         4       -         -
MEAN               9.00       .55     29.90      6.75     14.33      8.78      5.95      6.52       -         -
STD DEV            6.83      1.10     22.79      8.38     11.22      5.20      3.97      5.00       -         -

TS      12/ 6/78   645.      772.      801.      280.      383.      306.     2662.C     208.       -         -
         2/13/79   637.      622.      820.      254.      500.      241.      206.      196.       -         -
         5/ 2/79   677.      540.      863.      252.      403.      301.      186.      165.       -         -
         8/ 1/79   725.      764.      860.      263.      626.      347.      265.      233.       -         -
# OBS                 4         4         4         4         4         4         4         4       -         -
MEAN               671.      675.      836.      262.      478.      299.      219.      201.       -         -
STD DEV             40.      113.       30.       13.      111.       44.       41.       28.       -         -

TDS     12/ 6/78   582.      648.      795.      247.      369.      271.      355.      204.       -         -
         2/13/79   625.      568.      805.      242.      494.      210.      135.      168.       -         -
         5/ 2/79   640.      527.      861.      244.      398.      289.      189.      165.       -         -
         8/ 1/79   620.      683.      847.      260.      558.      323.      247.      189.       -         -
# OBS                 4         4         4         4         4         4         4         4       -         -
MEAN               617.      607.      827.      248.      455.      273.      232.      182.       -         -
STD DEV             25.       72.       32.        8.       87.       47.       94.       18.       -         -

NO3-N   12/ 6/78   .450     1.210      .010      .020      .010      .040      .170      .080       -         -
         2/13/79   -        1.100      .100     4.500      -         -          .390      .380       -         -
         5/ 2/79   .190     4.300      .100      .040      .130      .040      .500      .340       -         -
         8/ 1/79   .030     1.000      .050      .140      .150      .010      .200      .220       -         -
# OBS                 3         4         4         4         3         3         4         4       -         -
MEAN               .223     1.902      .065     1.175      .097      .030      .315      .255       -         -
STD DEV            .212     1.601      .044     2.217      .076      .017      .157      .135       -         -

NH3-N   12/ 6/78   .040      .030      .050 <    .020      .040      .060 <    .020 <    .020       -         -
         2/13/79 < .020 <    .020      .060 <    .020      .100      .140      .050      .040       -         -
         5/ 2/79   .190      .150      .320      .100      .240      .180      .090      .090       -         -
         8/ 1/79   .400      .300      .810      .350      .260      .500      .110      .050       -         -
# OBS                 4         4         4         4         4         4         4         4       -         -
MEAN               .157      .120      .310      .112      .160      .220      .063      .045       -         -
STD DEV            .181      .136      .356      .165      .107      .193      .049      .037       -         -

PO4-P   12/ 6/78   .016      .004      .024      .042      .008      .004      .028      .016       -         -
         2/13/79   .005      .007      .024      .035      .003      .012      .008      .012       -         -
         5/ 2/79 < .003 <    .003      .011 <    .003 <    .003      .014 <    .003 <    .003       -         -
         8/ 1/79 < .003      .009      .025      .001      .009 <    .003      .011      .004       -         -
# OBS                 4         4         4         4         4         4         4         4       -         -
MEAN               .005      .006      .021      .018      .005      .007      .012      .008       -         -
STD DEV            .008      .004      .007      .018      .004      .007      .012      .007       -         -
```

```
                                                                 PERMITTED SANITARY LANDFILL
                                                         MONITOR POINTS
PARAM    DATE              1         2         3         4         5         6         7         8         9        10

TKN      12/ 6/78       .08       .05       .21       .25       .18       .14 <     .02 <     .02         .         .
          2/13/79 <     .02 <     .02       .14 <     .02       .15       .17       .16       .16         .         .
          5/ 2/79       .19       .18       .57       .10       .47       .33       .15       .17         .         .
          8/ 1/79       .40       .34       .81       .40       .69       .50       .20       .25         .         .
# OBS                     4         4         4         4         4         4         4         4         .         .
MEAN                    .17       .14       .43       .19       .37       .29       .13       .15         .         .
STD DEV                 .17       .15       .31       .18       .26       .17       .09       .10         .         .

CU       12/ 6/78 <    .010 <    .010 <    .010 <    .010      .020 <    .010 <    .010 <    .010         .         .
          2/13/79 <    .010 <    .010 <    .010 <    .010 <    .010 <    .010 <    .010 <    .010         .         .
          5/ 2/79 <    .010 <    .010 <    .010 <    .010 <    .010 <    .010 <    .010 <    .010         .         .
          8/ 1/79 <    .010 <    .010 <    .010 <    .010 <    .010 <    .010 <    .010 <    .010         .         .
# OBS                     4         4         4         4         4         4         4         4         .         .
MEAN                   .000      .000      .000      .000      .005      .000      .000      .000         .         .
STD DEV                .000      .000      .000      .000      .010      .000      .000      .000         .         .

FE       12/ 6/78     5.770      .300      .830      .300      .300      .450      .060      .050         .         .
          2/13/79     2.480      .070      .210      .080 <    .010      .180      .100      .070         .         .
          5/ 2/79      .140      .070      .160      .070      .070      .090      .070      .080         .         .
          8/ 1/79     3.230      .280      .080      .040      .050      .350      .020      .040         .         .
# OBS                     4         4         4         4         4         4         4         4         .         .
MEAN                  2.905      .180      .320      .122      .105      .267      .063      .060         .         .
STD DEV               2.319      .127      .344      .120      .133      .163      .033      .018         .         .

MN       12/ 6/78      .260      .050      .060      .480      .070      .080      .040      .020         .         .
          2/13/79      .180      .020      .080      .040      .080      .100      .010      .010         .         .
          5/ 2/79      .170      .020      .050      .020      .070      .080 <    .010 <    .010         .         .
          8/ 1/79      .180      .070      .090      .020      .120      .130      .030      .030         .         .
# OBS                     4         4         4         4         4         4         4         4         .         .
MEAN                   .197      .040      .070      .140      .085      .097      .020      .015         .         .
STD DEV                .042      .024      .018      .227      .024      .024      .018      .013         .         .

NA       12/ 6/78    32.600     5.000   295.000    12.700    60.700    43.600    17.700    15.200         .         .
          2/13/79    34.000     4.200   252.000     8.600    75.000    35.000     9.800     8.000         .         .
          5/ 2/79    33.100     7.160   278.000    10.400    61.200    37.800     9.160     7.400         .         .
          8/ 1/79    33.000     7.300   246.000    21.000    70.000    30.000    20.000    13.000         .         .
# OBS                     4         4         4         4         4         4         4         4         .         .
MEAN                 33.175     5.915   267.750    13.175    66.725    36.600    14.165    10.900         .         .
STD DEV                .591     1.554    22.867     5.480     6.977     5.673     5.497     3.811         .         .

PB       12/ 6/78 <    .030 <    .030 <    .030 <    .030 <    .030 <    .030 <    .030 <    .030         .         .
          2/13/79 <    .030 <    .030 <    .030 <    .030 <    .030 <    .030 <    .030 <    .030         .         .
          5/ 2/79 <    .030 <    .030 <    .030 <    .030 <    .030 <    .030 <    .030 <    .030         .         .
          8/ 1/79 <    .030 <    .030 <    .030 <    .030 <    .030 <    .030 <    .030      .060         .         .
# OBS                     4         4         4         4         4         4         4         4         .         .
MEAN                   .000      .000      .000      .000      .000      .000      .000      .015         .         .
STD DEV                .000      .000      .000      .000      .000      .000      .000      .030         .         .

ZN       12/ 6/78      .300      .220      .020      .050      .030      .010      .240      .060         .         .
          2/13/79      .180      .340      .180      .030      .050      .440      .270      .160         .         .
          5/ 2/79      .020      .030      .030      .110      .080      .030      .050      .240         .         .
          8/ 1/79 <    .010      .010 <    .010 <    .010      .020 <    .010 <    .010 <    .010         .         .
# OBS                     4         4         4         4         4         4         4         4         .         .
MEAN                   .125      .150      .057      .047      .045      .120      .140      .115         .         .
STD DEV                .142      .154      .083      .046      .026      .214      .135      .106         .         .
```